APPENDIX A
ANALYSIS OF EFFECTS OF PROPOSED ACTION AND REASONABLE AND PRUDENT ALTERNATIVE ON SPECIES-LEVEL BIOLOGICAL REQUIREMENTS OF LISTED SPECIES

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ACRONYMS

BON	Bonneville Dam
CRI	cumulative risk initiative
CWT	coded wire tag
EM	delayed mortality of nontransported fish
ESU	evolutionarily significant units
FCRPS	Federal Columbia River Power System
HCP	Habitat Conservation Plan
LGR	Lower Granite Dam
MCR	Middle Columbia River
NMFS	National Marine Fisheries Service
PATH	Plan for Analyzing and Testing Hypotheses
PUD	public utility district
PSC	Pacific Salmon Commission
QAR	Quantitative Analytical Report
R/Sp	recruits-per-spawner
RPA	reasonable and prudent alternative
S	egg-to-adult survival, or survival during any component life stage
SAR	smolt-to-adult returns
SIMPAS	Simple Passage (model)
SR	Snake River
UCR	Upper Columbia River

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A.1 PURPOSE

This appendix documents the analysis the National Marine Fisheries Service (NMFS) used to estimate effects of a proposed action on the species-level biological requirements of listed Columbia River basin evolutionarily significant units (ESUs). Quantitative analytical results are one of several sources of information used to determine whether a proposed action jeopardizes listed species. Section 6.1.2 of the December 20, 2000, Federal Columbia River Power System (FCRPS) biological opinion (hereafter, Biological opinion) includes an overview of analytical methods, and Sections 6.3, 9.7.2, and 9.7.3.2 of the biological opinion contain summaries of the analytical results. The biological opinion references this appendix as a source for additional details regarding those sections.

A.2 INDICATOR CRITERIA

Section 1.3.1.1 of the biological opinion describes the general analytical approach that NMFS uses to apply the jeopardy standard in the implementing regulations (Section 402.02 - definition of "jeopardize the continued existence"). This general analytical approach states that, for an action to avoid jeopardy, the mortality of listed salmonids within the different ESUs attributable to the action must be low enough to meet the following condition:

> When combined with mortality occurring in other life stages, there is a high likelihood of population survival and a moderate to high likelihood of population recovery.

Most of the Columbia basin ESUs rely on a combined quantitative and qualitative approach to this determination. For most of the ESUs it is possible to quantify key aspects of the population dynamics and expected effects of the proposed action. These quantifications are imperfect, but NMFS considers them useful for organizing facts and hypotheses to support the general analysis. NMFS also considers qualitative factors affecting other life-stage survivals that could not be estimated quantitatively. For SR sockeye salmon, the entire analysis is qualitative.

In Section 1.3.1.2, NMFS identified "survival and recovery indicator criteria" that are useful for evaluating the general analytical approach described in Section 1.3.1.1. Table A-1 describes the four criteria.

NMFS considered all four criteria qualitatively, but, quantitatively, the 100-year extinction risk criterion is always harder to meet than the 24-year criterion, and the 48-year recovery criterion is always harder to meet than the 100-year criterion. For this reason, only the 100-year survival indicator criterion and the 48-year recovery indicator criterion are displayed in the biological opinion. This Appendix also estimates survival improvements necessary to meet the other criteria for comparison.

Table A-1. Summary of survival and recovery indicator criteria.

	24-Year Survival	100-Year Survival	48-Year Recovery	100-Year Recovery
Applies to:	All actions, including operation of the FCRPS, in combination	All actions, including operation of the FCRPS, in combination	All actions, including operation of the FCRPS, in combination	All actions, including operation of the FCRPS, in combination
Metric:	1 - the probability of absolute extinction in 24 years	1 - the probability of absolute extinction in 100 years	the probability that 8-year geometric mean abundance will be $\geq$ recovery abundance level in 100 years	the probability that 8-year geometric mean abundance will be $\geq$ recovery abundance level in 100 years
Acceptable Risk:	High probability (approximated as 5% or less risk of extinction)	High probability (approximated as 5% or less risk of extinction)	Moderate to high probability (approximated as 50% or greater likelihood of meeting the recovery abundance level in the specified time period)	Moderate to high probability (approximated as 50% or greater likelihood of meeting the recovery abundance level in the specified time period)

A.3 GENERAL APPROACH

Briefly, the analysis includes the steps illustrated in Figure A-1. The general approach is discussed in the five steps presented below and in Section 6.1.2 of the biological opinion.

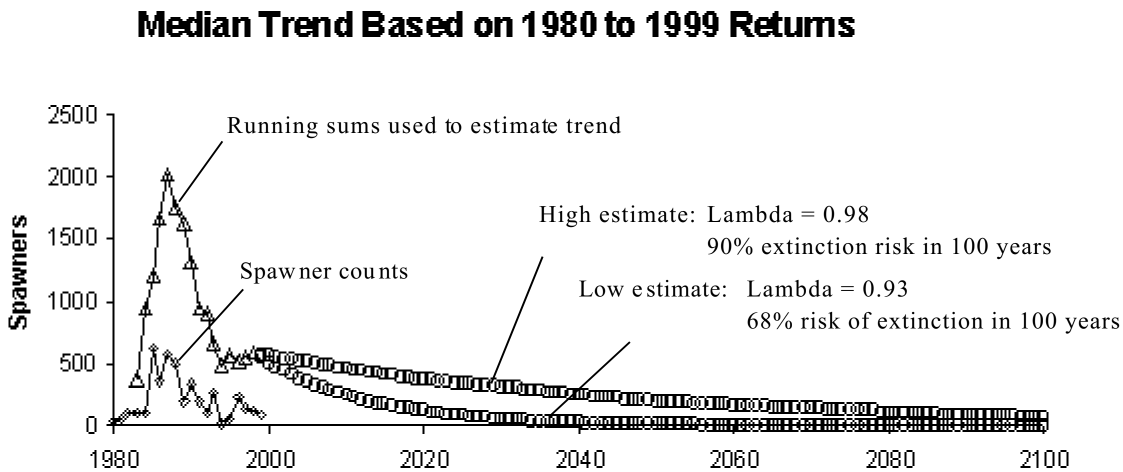
1) Define the recent population trend, based on adult returns from 1980 through the most recent year available.

The starting point is the NMFS cumulative risk initiative (CRI) analysis for 11 ESUs (McClure et al. 2000a,b,c) and the NMFS Quantitative Analytical Report (QAR) for the two Upper Columbia River ESUs (Cooney 2000). These reports assess population trends, based on adult returns during recent years. The trend is defined as the median annual population growth rate (lambda, λ). In the CRI analysis, this is estimated by methods described in McClure et al. (2000c) and Holmes (in review). Simply put, the analysis fits a stochastic exponential decline curve to running sums of total living current or future spawners. Cooney (2000) estimates population growth rate using a stochastic simulation model fit to adult spawner-to-spawner data.

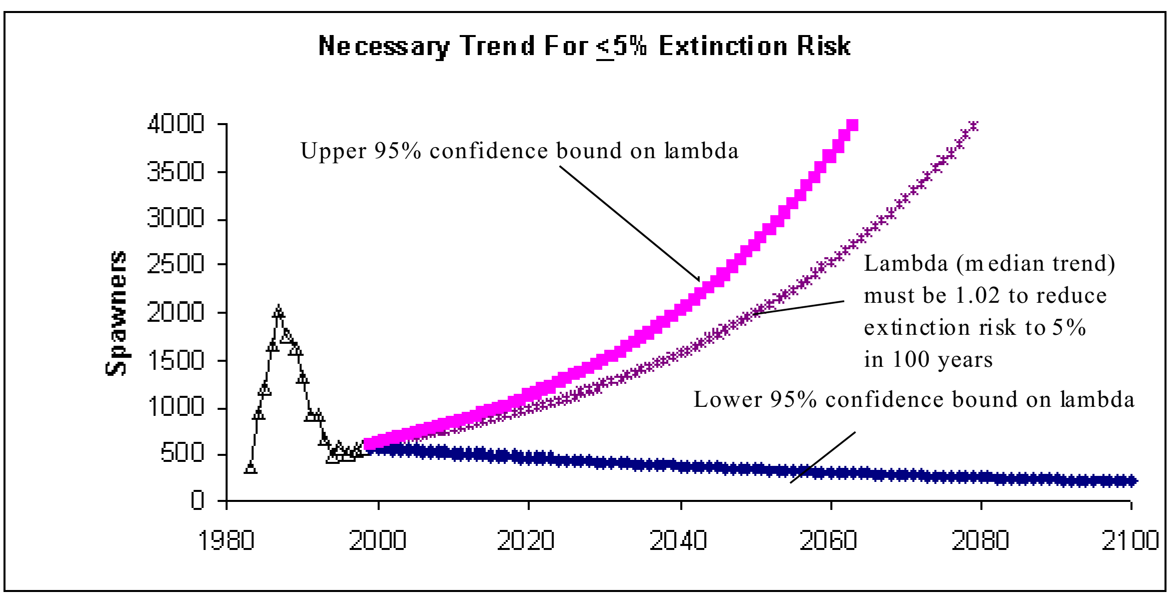
Since the primary purpose of the analysis is to determine the status of stocks and the risks they face under current conditions, NMFS restricted it to the years since 1980. Several agencies and organizations commented on the July 27, 2000, Draft Biological Opinion that NMFS should have included earlier starting years in its estimation of population trends. Changes to the hydrosystem were a main component of the choice of 1980 as the starting year, since before then, the hydrosystem on the Columbia River was in a state of flux. The final dam on the mainstem

Figure A-1. Primary steps in the analysis of effects of the action on species-level biological requirements for a hypothetical salmon population. Lambda is the median annual population growth rate.

Define the recent population trend, based on adult returns from 1980 through the most recent year available.



Define the change in trend that is necessary to meet the survival and recovery indicator criteria described in Section 1.3.1.

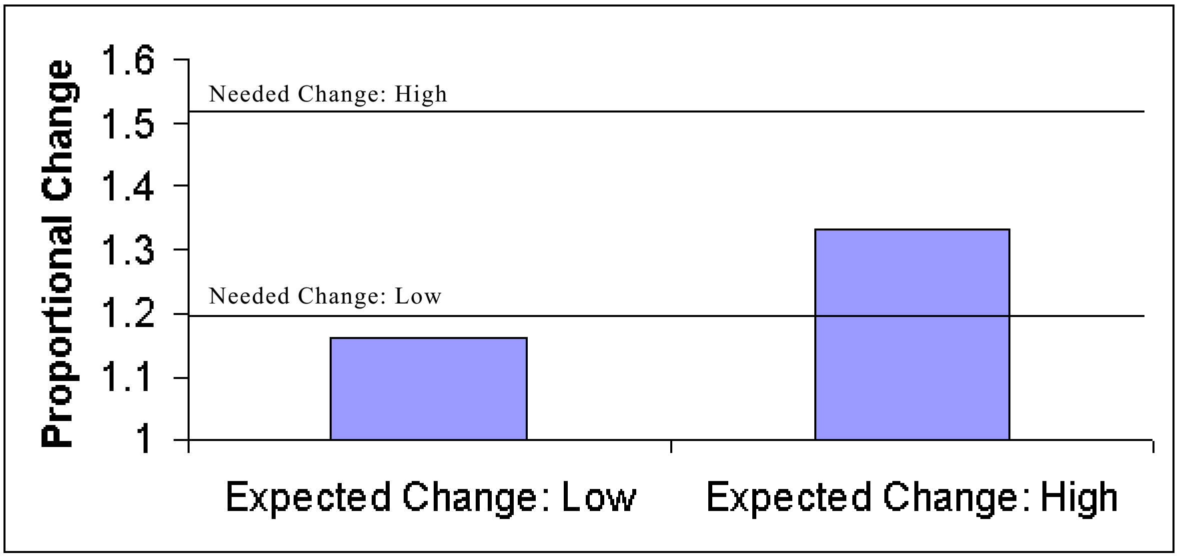


$$\text{Low Needed Survival Change} = \left(\frac{\text{Needed Lambda} = 1.02}{\text{Current Lambda} = 0.98}\right)^{\text{Mean Generation Time [4.5]}} = 1.20$$

$$\text{High Needed Survival Change} = \left(\frac{\text{Needed Lambda} = 1.02}{\text{Current Lambda} = 0.93}\right)^{\text{Mean Generation Time [4.5]}} = 1.52$$

Figure A-1 (Continued). Primary steps in the analysis of effects of the action on species-level biological requirements for a hypothetical salmon population. "Lambda" refers to the median annual population growth rate.

Estimate the change in survival rates associated with the proposed action and with expected changes in other life stages and update the estimate of population growth rate.



Compare the change in survival resulting from the proposed action with the necessary change defined in step 2.

In the example, the highest estimate of the expected survival change achieves the lowest estimate of the goal but the lowest estimate does not. In the worst case, an additional 31% (1.31 times "Low" expected survival rate) survival improvement is still necessary to meet the highest estimate of the goal.

Qualitatively evaluate the likelihood that survival through life stages that could not be quantified is likely to sufficiently reduce the additional necessary survival change.

Relies on information in Basinwide Recovery Strategy

Columbia was completed in 1971, the last of the four lower Snake River dams was completed in 1975, and the full complement of turbines was installed by 1979. The reservoir storage capacity in the Columbia was nearly doubled in 1975, when Libby and Mica dams were completed. Including data from before 1980 would, therefore, confound the evaluation of the current status by implicitly incorporating conditions that no longer exist. The evaluation would also be confounded for other reasons, such as the oceanic regime shift that occurred in the late 1970s (Mantua et al. 1997).

Agencies and organizations commented on the choice of median annual population growth rate as the measure of current trends in the July 27, 2000, Draft Biological Opinion and the anadromous fish appendix. Commenters expressed computational concerns and confusion because NMFS' methods for estimating lambda changed. Many of the suggestions are reflected in the current analysis. The exact methods are now available in McClure et al. (2000c) and Holmes (in review). Some agencies and organizations suggested using alternative indicators of population trend, such as recruits-per-spawner (R/Sp) and smolt-to-adult returns (SARs). Use of median annual population growth rate yields results nearly identical to R/Sp if recruits are defined as adults reaching the spawning grounds. Use of R/Sp with recruits expressed at other life stages, such as adults to the Columbia River mouth, and use of SARs yield estimates of trend for only part of the life cycle. Unless survival is assumed constant in the other life stages, these measures are not useful for assessing population trends.

NMFS also received comments that the annual population growth rate, as determined in McClure et al. (2000), is very sensitive to start- and end-points of the time period selected for the analysis and to data points considered outliers. NMFS applies running sums to the abundances, which reduces the influence of individual years. However, NMFS agrees in general with the comment. In response, NMFS developed an alternative method of estimating the mean instantaneous rate of population change (μ, which, in turn, is used to estimate lambda; McClure et al. 2000c) that is less sensitive to these factors. The alternative estimate and the estimates of annual population growth rate used in this biological opinion vary, but for 80% of all spawning aggregations, the two estimates differ by an absolute value of less than 0.05 (McClure 2000). Whereas this method reduces the sensitivity to time period (or outliers), the implications for estimates of extinction risk, which are sensitive to data distribution, are not well understood. Additional research is needed to determine whether this method, or an alternative, best addresses the sensitivity of NMFS' analytical method to start- and end-points and extreme values. NMFS has not used this new method in this biological opinion, therefore, but considers this characteristic of the analysis qualitatively when drawing conclusions.

2) Define the change in the trend that is necessary to meet the survival and recovery indicator criteria described in Section 1.3.1 of the biological opinion.

Both McClure et al. (2000b,c) and Cooney (2000) estimated the proportional change in population growth rate necessary to reduce extinction risk to 5% in 24 and 100 years. That change in population growth rate can be translated into a needed change in survival if the mean generation time is known:

(1) $$\Delta S = \Delta\lambda^{\text{mean generation time}}$$

where $\Delta\lambda$ is the multiplicative change in median annual population growth rate (based on 1980 to most recent available year), and ΔS is the multiplicative change in average egg-to-adult survival, or survival during any component life stage, that corresponds to the return years used to estimate $\Delta\lambda$.

McClure et al. (2000b,c) used diffusion approximation methods (Dennis et al. 1991; Holmes in review) to project future population trajectories and estimate extinction risk for the survival indicator criterion. Cooney (2000) used a cohort replacement model (Botsford and Brittinacher 1998) to do the same. Neither approach includes density dependence at the low population levels evaluated in the estimation of extinction risk. A few agencies and organizations that commented on the July 27, 2000, Draft Biological Opinion suggested including density dependence at low population levels, and the Idaho Department of Fish and Game suggested including depensation at low population levels. NMFS' assumption of density independence at low population levels is more conservative (i.e., results in higher risk of extinction) than models based on density dependence, such as those based on Ricker functions. A model based on depensation may yield more conservative results, but parameterization of such a model for the populations under consideration must be based almost exclusively on guesswork.

NMFS evaluated the recovery indicator criteria for stocks with interim recovery abundance levels using either simulations with the cohort replacement model for UCR stocks (Cooney 2000), or with an estimate of the minimum change in survival that would be necessary to grow from the current abundance level to the recovery abundance level in either 48 or 100 years (Schiewe 2000). The first method includes assumptions regarding density dependence as populations approach the recovery abundance level; the second method assumes continued exponential growth near recovery abundance levels. Several agencies and organizations, when commenting on the July 27, 2000, Draft Biological Opinion, criticized the absence of density dependance at high abundence levels using this second approach. NMFS agrees that density dependence probably occurs at some high abundance level. The difficulty is in defining the capacity of the system and the rate at which productivity declines as that capacity is approached. NMFS has been unable to detect density dependence since 1980 for Columbia River basin stocks (McClure et al. 2000c) and questions the data quality and conclusions from analyses that have been based on longer time-series (Schaller et al. 1999; Zabel and Williams 2000; Schaller et al. 2000). With the exception of the QAR analysis for UCR spring chinook and UCR steelhead, therefore, analyses of the survival changes necessary to meet recovery indicator criteria do not include density dependence. NMFS qualitatively considers the likelihood that these are, however, minimum estimates in its jeopardy determination.

NMFS applies a simple method of estimating the minimum survival change necessary to meet the recovery indicator criteria for stocks lacking an interim recovery abundance level. As described in Section 1.3.1, the recovery abundance level may be unknown, but it is certainly higher than the current abundance level. At a minimum, therefore, the median annual population growth rate must be > 1.0. The necessary change in lambda is determined by simply dividing 1.0 by the estimate of lambda from the first step of the analysis.

3) Estimate the change in survival rates associated with the proposed action and with expected changes in other life stages, and update the estimate of population growth rate.

The necessary survival changes identified in the second step of the analysis are based on the assumption that life-stage survival rates influencing adult returns in 1980 through the most recent available year will continue indefinitely. The survival rate associated with the proposed action may, however, represent an improvement over the average survival rate influencing the 1980-through-the-most-recent adult returns. Current survival in other life stages may also differ from the 1980-through-the-most-recent-year average. If these current or expected survival rates are expected to continue, they will change the population growth rate.

NMFS estimates FCRPS juvenile and adult survival resulting from the proposed action using the methods defined in Section 6.1.1 of the biological opinion. The change for each species is addressed separately for each ESU. In some cases, retrospective modeling analyses are available for comparison (e.g., Plan for Analyzing and Testing Hypotheses [PATH] juvenile passage survival estimates for SR spring/summer and fall chinook). In other cases, inferences must be drawn from other species or geographic areas. NMFS also estimates expected survival associated with current and future harvest rates, based on actions defined in the Basinwide Recovery Strategy, and compares that with average historical harvest rates. The combined change in survival is the product of the survival change expected from the proposed action and that expected from current harvest rates. For example, if the average smolt survival through the hydrosystem averaged 50% for the migration years corresponding to the risk assessment and is expected to be 55% as a result of the proposed action, a 10% survival improvement is expected (0.55/0.50 = 1.10). If current and future harvest management results in a 5% survival improvement, the combined change is 15.5% (1.10 x 1.05 = 1.155).

NMFS was not able to quantify expected changes in survival resulting from habitat and hatchery management actions in this analysis. Those effects are evaluated qualitatively relative to the remaining survival change needed after implementing the proposed action (see Step 5 below).

The analysis of survival changes used in this biological opinion is identical to that used for SR steelhead in the July 27, 2000, Draft Biological Opinion and for the evaluation of alternative harvest strategies in McClure et al. (2000c), but is simpler than the Leslie matrix approach that was applied to other ESUs in the draft (Leslie 1945,1948). The primary reason for the change is that applying the Leslie matrix requires an estimate of survival through all life stages, while the method used here requires only estimates of survival changes for life stages that are affected by the proposed action, or that have been affected by changes in other management actions. The matrix approach is useful (Kareiva et al. 2000; Cooney 2000), but it is unnecessarily complex for the analysis required in the biological opinion. Technical discussions with other agencies and organizations on the July 27, 2000, draft sometimes focused on estimating survival rates that were not critical to the results and generated debates regarding differences between estimates of population growth rate from the deterministic Leslie matrix and the stochastic modified Dennis model approach. The current method simply updates the original estimate of median annual population growth rate (λ) according to a generalized form of Equation 11 in McClure et al. (2000c):

(2) $\lambda_{NEW} = \lambda_{OLD}$ * (new life-stage survival rate/old life-stage survival rate)$^{1/\text{mean generation time}}$

4) Compare the change in survival resulting from the proposed action with the necessary change defined in step 2.

NMFS constructed ratios that indicate the degree to which the proposed action meets the survival and recovery indicator criteria. Ratios less than, or equal to, 1.0 indicate that the jeopardy standard indicator criteria are met, given the effects of the proposed action and other expected activities. Values over 1.0 indicate that additional improvements in survival are necessary to meet the criterion. Those values represent the multiplier by which survival, after the proposed action and other expected actions are implemented, must be additionally increased.

5) Qualitatively evaluate the likelihood that survival through life stages that could not be quantified is likely to reduce the additional necessary survival change.

The quantitative analysis described above does not include changes in survival in other life stages that result from habitat or hatchery management. NMFS must use a combination of qualitative methods and professional judgment to determine the extent to which changes in other life stages might account for the necessary survival improvements. Survival changes can be expected if there have been changes from the average 1980-to-1999 egg-to-smolt survival, estuary survival, and/or prespawning adult (above the uppermost dam) survival rates. Also, because the quantitative analysis does not include the effects of FCRPS operations on some life stages in some ESUs (e.g., spawning and rearing requirements of LCR chinook salmon and CR chum salmon), the effects must also be evaluated qualitatively. For SR sockeye salmon, this is the only type of analysis NMFS can perform, because the information available is not suitable for calculating an estimate of current demographic risks, let alone expected survival improvements under the proposed action.

For these reasons, this qualitative evaluation is a key factor in the jeopardy determination for each ESU. Among the factors that NMFS considers at this step are the effects of the proposed action on critical habitat in the action area in the overall context of all the effects on biological requirements throughout the life cycle. The evaluation draws on a review of the existing literature, including the information summarized in Section 4.1 and Appendix C of the biological opinion. Adverse effects on individuals of a species or constituent elements or segments of critical habitat generally do not result in jeopardy or determination of adverse modifications unless those losses, when added to the environmental baseline, are likely to result in significant adverse affects throughout the species' range, or appreciably diminish the value of the critical habitat for both the survival and the recovery of the listed species (50 CFR Section 402.02). Therefore, NMFS considers the range of critical habitat types affected by the proposed action, the geographic scope of the effects, and the degree to which the effects are likely to limit the productivity of each ESU.

A.4 ESTIMATES OF NEEDED IMPROVEMENT FROM BASE PERIOD SURVIVAL

In the first two steps of the analysis, NMFS must estimate the current trend and the survival change that are necessary to meet survival and recovery indicator criteria. The following two subsections discuss the estimates of the necessary survival improvements and the key assumptions influencing those estimates.

A.4.1 SURVIVAL AND RECOVERY INDICATOR CRITERIA

Tables A-2 through A-6 display estimates of the improvement from base period survival needed to meet the four survival and recovery indicator criteria. All results are expressed as multipliers to either median annual population growth rate (λ) or per-generation (egg-to-adult spawner) survival (S).

CRI Estimates. CRI estimates are available for 12 of the 13 ESUs in the Columbia River basin. McClure et al. (2000b) is the source of CRI estimates of the current median annual population growth rate (lambda), based on returning spawners from 1980 through the most recently available year. McClure et al. (2000b) is also the source of estimates of the change in lambda that is needed to meet the 24- and 100-year survival indicator criteria. Methods are described in McClure et al. (2000c).

NMFS generated estimates of the change necessary to meet recovery indicator criteria from McClure et al.'s (2000b) lambda estimates. NMFS used two alternative methods, depending upon whether or not interim recovery abundance levels were defined for an ESU. Interim recovery abundance levels have been defined only for SR spring/summer chinook index stocks, SR fall chinook, SR sockeye salmon, UCR spring chinook, and UCR steelhead (Appendix C). For each of these ESUs except SR sockeye salmon, which was not evaluated in this analysis, NMFS used the method of estimating recovery indicator criteria described in Schiewe (2000). Because that document is not easily accessible, the method is briefly described here. Needed changes in annual population growth rate were calculated using Equation 3:

(3) $\lambda_{needed} = (\boldsymbol{n}_{goal} \div \boldsymbol{n}_{current})^{(1\,/\,\mathbf{t})}$

Where:

λ_{needed} is the geometric mean annual population growth rate that would yield the interim recovery abundance level in the desired time, $\boldsymbol{n}_{\mathrm{goal}}$ is the interim recovery abundance level (Appendix C, expressed as the 8-year geometric mean of spawner numbers), $\boldsymbol{n}_{current}$ is the current number of spawners (expressed as the geometric mean of the most recent 8 years), and $\boldsymbol{t}$ is the time period over which recovery goals are to be achieved (44 or 96 years, corresponding to midpoints of 8-year geometric means in 48 and 100 years). The most recent 8-year geometric mean spawner

Table A-2. Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years. A "Necessary % Change in Lambda" of, for example, 15.00 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.15 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 81.12 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.8112 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Spring/Summer Chinook																	
Aggregate ESU	4.73	0.91	0.91	0.00	0.00	0.82	0.82	0.00	0.00								
Bear Valley/Elk Creeks	4.729	1.02	1.02	0.00	0.00	1.02	1.02	0.00	0.00	1.03	1.03	0.00	0.00	1.03	1.03	0.00	0.00
Imnaha River[1]	4.486	0.89	0.89	0.00	0.00	0.88	0.88	0.00	0.00	0.92	0.92	0.00	0.00	0.91	0.91	0.00	0.00
Johnson Creek	4.351	1.01	1.01	0.00	0.00	1.01	1.01	0.00	0.00	1.03	1.03	0.00	0.00	1.03	1.03	0.00	0.00
Marsh Creek	4.684	0.99	0.99	0.00	0.00	0.99	0.99	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00
Minam River	4.178	0.98	0.98	0.00	0.00	0.93	0.93	0.00	0.00	1.02	1.02	0.00	0.00	0.97	0.97	0.00	0.00
Poverty Flats	4.221	1.00	1.00	0.00	0.00	0.99	0.99	0.00	0.00	1.02	1.02	0.00	0.00	1.02	1.02	0.00	0.00
Sulphur Creek	4.610	1.04	1.04	0.00	0.00	1.04	1.04	0.00	0.00	1.05	1.05	0.00	0.00	1.05	1.05	0.00	0.00
1 50%, rather than 20%, effectiveness of hatchery-origin natural spawners was applied to the Imnaha index stock.																	
Alturas Lake Creek	4.465	0.75				0.75											
American River	4.465	0.91				0.91											
Big Sheep Creek	4.465	0.88				0.85											
Beaver Creek	4.465	0.95				0.95											
Bushy Fork	4.465	0.98				0.98											
Camas Creek	4.465	0.92				0.92											
Cape Horn Creek	4.465	1.05				1.05											
Catherine Creek	4.465	0.85				0.78											
Catherine Creek N Fk	4.465	0.92				0.92											
Catherine Creek S Fk	4.465	0.80				0.80											
Crooked Fork	4.465	1.00				1.00											
Grande Ronde River	4.465	0.84				0.77											
Knapp Creek	4.465	0.89				0.89											
Lake Creek	4.465	1.06				1.06											
Lemhi River	4.465	0.98				0.98											
Lookingglass Creek	4.465	0.79				0.72											
Loon Creek	4.465	1.00				1.00											
Lostine Creek	4.465	0.90				0.87											
Lower Salmon River	4.465	0.92				0.92											

Table A-2 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years. A "Necessary % Change in Lambda" of, for example, 15.00 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.15 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 81.12 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.8112 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Lower Valley Creek	4.465	0.92				0.92											
Moose Creek	4.465	0.94				0.94											
Newsome Creek	4.465	1.03				1.03											
Red River	4.465	0.91				0.91											
Salmon River E. Fork	4.465	0.94				0.94											
Salmon River S. Fork	4.465	1.06				1.06											
Secesh River	4.465	0.98				0.98											
Selway River	4.465	0.91				0.91											
Sheep Creek	4.465	0.80				0.80											
Upper Big Creek	4.465	0.97				0.97											
Upper Salmon River	4.465	0.90				0.90											
Upper Valley Creek	4.465	1.03				1.03											
Wallowa Creek	4.465	0.86				0.86											
Wenaha River	4.465	0.90				0.84											
Whitecap Creek	4.465	0.90				0.90											
Yankee Fork	4.465	0.88				0.88											
Yankee West Fork	4.465	0.99				0.99											
Snake River Fall Chinook																	
Aggregate	4.137	0.92	0.92	0.00	0.00	0.87	0.87	0.00	0.00								
Upper Columbia River Spring Chinook																	
ESU Aggregate - CRI	4.25	0.85	0.85	0.00	0.00	0.84	0.96	15.00	81.12								
Methow River - QAR	4.400	0.90	0.92	2.61	12.00	0.90	0.91	0.95	12.00								
Entiat River - QAR	4.320	0.89	0.89	0.00	0.00	0.89	0.89	0.00	0.00								
Wenatchee R. - QAR	4.370	0.88	0.89	1.56	7.00	0.88	0.89	0.97	7.00								
Methow River - CRI	4.250	0.86	0.95	10.50	52.86	0.85	0.94	10.50	52.86	0.89	0.97	8.5	1.41	0.870	0.95	9.5	1.47
Entiat River - CRI	4.210	0.85	0.86	1.00	4.28	0.81	0.87	6.50	30.36	0.89	0.89	0.0	1.00	0.852	0.86	1.5	1.06
Wenatchee River - CRI	4.336	0.80	0.80	0.00	0.00	0.80	0.80	0.50	2.19	0.85	0.85	0.0	1.00	0.841	0.84	0.0	1.00

Table A-2 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years. A "Necessary % Change in Lambda" of, for example, 15.00 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.15 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 81.12 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.8112 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Upper Willamette River Chinook																	
McKenzie River above Leaburg	4.430	0.99	0.99	0.00	0.00	0.90	0.90	0.00	0.00								
Lower Columbia River Chinook																	
Aggregations Above Bonneville Dam:																	
(Insufficient Information For Analysis)																	
Aggregations Below Bonneville Dam:																	
Bear Creek	3.29	0.82	0.94	13.50	51.68	0.73	0.92	26.00	113.90								
Big Creek	3.96	0.93	0.93	0.00	0.00	0.84	0.84	0.00	0.00								
Clatskanie	3.68	0.89	1.16	31.00	169.76	0.80	1.13	42.00	262.79								
Cowlitz Tule	3.56	0.92															
Elochoman	3.50	0.99															
Germany	3.68	0.93															
Gnat	3.74	0.94	1.08	15.50	71.42	0.84	1.06	26.00	137.35								
Grays Tule	3.53	0.85															
Kalama Spring	3.77	0.85															
Kalama	3.77	0.99															
Klaskanine	3.68	0.89	1.08	21.00	101.48	0.80	1.06	32.50	181.28								
Lewis R Bright	3.84	0.99															
Lewis Spring	3.84	0.91															
Lewis, E Fk Tule	3.84	0.99															
Lewis and Clark	3.84	0.54															
Mill Fall	3.68	0.81	0.92	14.00	61.85	0.72	0.90	24.50	123.74								
Plympton	3.83	0.95	0.95	0.00	0.00	0.86	0.86	0.00	0.00								
Sandy Late	3.68	0.98	0.98	0.00	0.00	0.98	0.98	0.00	0.00								
Skamokawa	3.68	0.82															
Youngs	3.68	0.94	1.58	67.50	565.66	0.84	1.49	76.50	706.84								

Table A-2 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years. A "Necessary % Change in Lambda" of, for example, 15.00 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.15 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 81.12 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.8112 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Steelhead																	
ESU Aggregate	5.168	0.83	0.83	0.00	0.00	0.72	0.72	0.00	0.00								
A-Run Aggregate	5.040	0.85	0.85	0.00	0.00	0.74	0.74	0.00	0.00								
A-Run Pseudopopulation	5.040	0.85	0.85	0.00	0.00	0.74	0.74	0.00	0.00								
B-Run Aggregate	6.490	0.84	0.84	0.00	0.00	0.74	0.74	0.00	0.00								
B-Run Pseudopopulation	6.490	0.84	0.84	0.00	0.00	0.74	0.74	0.00	0.00								
Upper Columbia River Steelhead																	
ESU Aggregate - CRI	3.784	0.83	0.83	0.00	0.00	0.69	0.74	7.00	29.18								
Methow - QAR	3.800	0.97	0.97	0.00	0.00	0.81	0.81	0.00	0.00								
Wenatchee/Entiat - QAR	3.800	0.94	0.94	0.00	0.00	0.85	0.85	0.00	0.00								
Mid-Columbia River Steelhead																	
ESU Aggregate	5.17	0.84				0.77											
Deschutes River Sum	5.169	0.84	0.84	0.00	0.00	0.77	0.77	0.00	0.00								
Warm Springs NFH Sum	5.169	0.91	0.91	0.00	0.00	0.91	0.91	0.00	0.00								
Umatilla River Sum	5.169	0.90	0.90	0.00	0.00	0.90	0.90	0.00	0.00								
Yakima River Sum	5.169	1.04	1.04	0.00	0.00	1.01	1.01	0.00	0.00								
Upper Willamette River Steelhead																	
ESU Aggregate	4.08	0.92	0.92	0.00	0.00	0.88	0.88	0.00	0.00								
Mollala	4.080	0.91	0.91	0.00	0.00	0.84	0.84	0.00	0.00								
N Santiam River	4.080	0.92	0.92	0.00	0.00	0.89	0.89	0.00	0.00								
S Santiam	4.080	0.94	0.94	0.00	0.00	0.87	0.87	0.00	0.00								
Calapooia	4.080	0.93	0.93	0.00	0.00	0.93	0.93	0.00	0.00								

Table A-2 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years. A "Necessary % Change in Lambda" of, for example, 15.00 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.15 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 81.12 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.8112 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Lower Columbia River Steelhead																	
ESU Aggregate	4.47	0.91				0.80											
Aggregations Above Bonneville Dam:																	
(Insufficient Information For Analysis)																	
Aggregations Below Bonneville Dam:																	
Clackamas summer	5.17	0.83	0.83	0.00	0.00	0.73	0.73	0.00	0.00								
Clackamas winter	4.47	0.88	0.88	0.00	0.00	0.76	0.76	0.00	0.00								
Green River winter	4.47	0.90	0.91	0.50	2.25	0.90	0.91	0.50	2.25								
Kalama summer	5.17	0.91	0.91	0.00	0.00	0.77	0.77	0.00	0.00								
Kalama River winter	4.47	0.97	0.97	0.00	0.00	0.90	0.90	0.00	0.00								
Sandy winter	4.47	0.91	0.91	0.00	0.00	0.85	0.85	0.00	0.00								
Toutle winter	4.47	0.88	0.88	0.00	0.00	0.88	0.88	0.00	0.00								
Columbia River Chum Salmon																	
ESU Aggregate	3.61	1.04				1.04											
Aggregations Above Bonneville Dam:																	
(Insufficient Information For Analysis)																	
Aggregations Below Bonneville Dam:																	
Grays River west fork	3.61	1.23				1.23											
Grays River mouth to head	3.61	0.96				0.96											
Hardy Creek	3.61	1.05				1.05											
Crazy Johnson	3.61	1.16				1.16											
Hamilton	3.61	0.92				0.92											
Hamilton Springs	3.61	1.11				1.11											

Table A-3. Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years. A "Necessary % Change in Lambda" of, for example, 1.50 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.015 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 7.30 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.073 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Spring/Summer Chinook																	
Aggregate ESU	4.73	0.91	0.93	1.50	7.30	0.82	0.93	14.00	85.83								
Bear Valley/Elk Creeks	4.729	1.02	1.02	0.00	0.00	1.02	1.02	0.00	0.00	1.03	1.03	0.000	0.00	1.03	1.03	0.000	0.00
Imnaha River[1]	4.486	0.89	0.96	7.50	38.32	0.88	0.96	9.50	50.24	0.92	0.95	3.500	16.69	0.91	0.96	5.500	27.15
Johnson Creek	4.351	1.01	1.01	0.00	0.00	1.01	1.01	0.00	0.00	1.03	1.03	0.000	0.00	1.03	1.03	0.000	0.00
Marsh Creek	4.684	0.99	1.02	3.00	14.85	0.99	1.02	3.00	14.85	1.00	1.01	0.500	2.36	1.00	1.01	0.500	2.36
Minam River	4.178	0.98	1.02	4.50	20.19	0.93	1.02	9.50	46.11	1.02	1.02	0.000	0.00	0.97	1.02	5.000	22.61
Poverty Flats	4.221	1.00	1.00	0.00	0.00	0.99	0.99	0.00	0.00	1.02	1.02	0.000	0.00	1.02	1.02	0.000	0.00
Sulphur Creek	4.610	1.04	1.11	7.00	36.60	1.04	1.11	7.00	36.60	1.05	1.09	3.500	17.19	1.05	1.09	3.500	17.19
1 50%, rather than 20%, effectiveness of hatchery-origin natural spawners was applied to the Imnaha index stock.																	
Alturas Lake Creek	4.465	0.75				0.75											
American River	4.465	0.91				0.91											
Big Sheep Creek	4.465	0.88				0.85											
Beaver Creek	4.465	0.95				0.95											
Bushy Fork	4.465	0.98				0.98											
Camas Creek	4.465	0.92				0.92											
Cape Horn Creek	4.465	1.05				1.05											
Catherine Creek	4.465	0.85				0.78											
Catherine Creek N. Fork	4.465	0.92				0.92											
Catherine Creek S. Fork	4.465	0.80				0.80											
Crooked Fork	4.465	1.00				1.00											
Grande Ronde River	4.465	0.84				0.77											
Knapp Creek	4.465	0.89				0.89											
Lake Creek	4.465	1.06				1.06											
Lemhi River	4.465	0.98				0.98											
Lookingglass Creek	4.465	0.79				0.72											
Loon Creek	4.465	1.00				1.00											
Lostine Creek	4.465	0.90				0.87											
Lower Salmon River	4.465	0.92				0.92											
Lower Valley Creek	4.465	0.92				0.92											

Table A-3 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years. A "Necessary % Change in Lambda" of, for example, 1.50 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.015 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 7.30 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.073 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Moose Creek	4.465	0.94				0.94											
Newsome Creek	4.465	1.03				1.03											
Red River	4.465	0.91				0.91											
Salmon River E. Fork	4.465	0.94				0.94											
Salmon River S. Fork	4.465	1.06				1.06											
Secesh River	4.465	0.98				0.98											
Selway River	4.465	0.91				0.91											
Sheep Creek	4.465	0.80				0.80											
Upper Big Creek	4.465	0.97				0.97											
Upper Salmon River	4.465	0.90				0.90											
Upper Valley Creek	4.465	1.03				1.03											
Wallowa Creek	4.465	0.86				0.86											
Wenaha River	4.465	0.90				0.84											
Whitecap Creek	4.465	0.90				0.90											
Yankee Fork	4.465	0.88				0.88											
Yankee West Fork	4.465	0.99				0.99											
Snake River Fall Chinook																	
Aggregate	4.137	0.92	0.96	5.00	22.37	0.87	0.95	8.50	40.15								
Upper Columbia River Spring Chinook																	
ESU Aggregate - CRI	4.25	0.85	0.96	14.00	74.52	0.84	0.96	15.00	81.12								
Methow River - QAR	4.400	0.90	0.96	6.51	32.00	0.90	0.90	0.87	32.00								
Entiat River - QAR	4.320	0.89	0.99	11.01	57.00	0.89	0.90	0.79	57.00								
Wenatchee River - QAR	4.370	0.88	1.00	13.66	75.00	0.88	0.88	0.75	75.00	0.92	1.00	8.00	40.00	0.82	0.88	8.00	40.00
Methow River - CRI	4.250	0.86	1.05	22.00	132.82	0.85	1.04	23.00	141.04	0.89	1.07	19.5	2.13	0.870	1.06	21.5	2.29
Entiat River - CRI	4.210	0.85	0.98	15.00	80.11	0.81	0.99	21.50	127.02	0.89	0.98	10.5	1.52	0.852	0.99	16.0	1.87
Wenatchee River - CRI	4.336	0.80	0.96	20.00	120.46	0.80	0.96	21.00	128.54	0.85	0.97	13.5	1.73	0.841	0.96	14.5	1.80

Table A-3 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years. A "Necessary % Change in Lambda" of, for example, 1.50 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.015 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 7.30 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.073 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
<u>Upper Willamette River Chinook</u>																	
McKenzie River above Leaburg	4.430	0.99	1.01	2.00	9.17	0.90	1.01	12.00	65.21								
<u>Lower Columbia River Chinook</u>																	
Aggregations Above Bonneville Dam:																	
Bear Creek	3.29	0.82	1.04	26.00	113.90	0.73	1.03	41.5	213.32								
Big Creek	3.96	0.93	0.96	2.50	10.27	0.84	0.95	13.00	62.25								
Clatskanie	3.68	0.89	1.19	34.00	193.16	0.80	1.17	47.00	311.99								
Cowlitz Tule	3.56	0.92															
Elochoman	3.50	0.99															
Germany	3.68	0.93															
Gnat	3.74	0.94	1.14	21.50	107.16	0.84	1.12	33.50	194.65								
Grays Tule	3.53	0.85															
Kalama Spring	3.77	0.85															
Kalama	3.77	0.99															
Klaskanine	3.68	0.89	1.12	25.50	130.42	0.80	1.10	38.00	226.63								
Lewis River Bright	3.84	0.99															
Lewis Spring	3.84	0.91															
Lewis, E Fk Tule	3.84	0.99															
Lewis and Clark	3.84	0.54															
Mill Fall	3.68	0.81	1.03	27.50	144.20	0.72	1.02	41.50	258.12								
Plympton	3.83	0.95	0.99	4.50	18.36	0.86	0.99	15.50	73.66								
Sandy Late	3.68	0.98	0.98	0.00	0.00	0.98	0.98	0.00	0.00								
Skamokawa	3.68	0.82															
Youngs	3.68	0.94	1.58	68.00	572.99	0.84	1.50	78.00	732.33								
<u>Snake River Steelhead</u>																	
ESU Aggregate	5.168	0.83	0.90	8.00	48.84	0.72	0.89	23.00	191.49								
A-Run Aggregate	5.040	0.85	0.90	5.50	30.98	0.74	0.89	20.00	150.65								
A-Run Pseudopopulation	5.040	0.85	0.92	8.00	47.39	0.74	0.91	22.50	178.10								

Table A-3 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years. A "Necessary % Change in Lambda" of, for example, 1.50 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.015 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 7.30 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.073 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
B-Run Aggregate	6.490	0.84	0.93	11.00	96.85	0.74	0.92	23.50	293.48								
B-Run Pseudopopulation	6.490	0.84	0.94	12.00	108.65	0.74	0.93	24.50	314.62								
Upper Columbia River Steelhead																	
ESU Aggregate - CRI	3.784	0.83	0.95	13.50	61.47	0.69	0.94	37.00	229.12								
Methow - QAR	3.800	0.97	1.00	3.75	15.00	0.81	0.85	5.24	115.00								
Wenatchee/Entiat - QAR	3.800	0.94	0.97	3.03	12.00	0.85	0.88	4.37	67.00								
Mid-Columbia River Steelhead																	
ESU Aggregate	5.17	0.84				0.77											
Deschutes River summer	5.169	0.84	0.92	9.00	56.12	0.77	0.92	19.50	151.14								
Warm Springs NFH summer	5.169	0.91	0.97	7.50	45.33	0.91	0.97	7.50	45.33								
Umatilla River summer	5.169	0.90	0.93	3.00	16.51	0.90	0.93	2.50	13.61								
Yakima River summer	5.169	1.04	1.04	0.00	0.00	1.01	1.01	0.00	0.00								
Upper Willamette River Steelhead																	
ESU Aggregate	4.08	0.92	0.95	3.00	12.82	0.88	0.95	8.50	39.49								
Mollala	4.080	0.91	0.98	7.50	34.32	0.84	0.99	18.00	96.46								
N Santiam River	4.080	0.92	0.96	4.50	19.67	0.89	0.96	7.50	34.32								
S Santiam	4.080	0.94	0.95	1.50	6.26	0.87	0.96	10.50	50.29								
Calapooia	4.080	0.93	1.03	11.00	53.08	0.93	1.03	11.00	53.08								
Lower Columbia River Steelhead																	
ESU Aggregate	4.47	0.91				0.80											

Table A-3 (continued). Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years. A "Necessary % Change in Lambda" of, for example, 1.50 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.015 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 7.30 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.073 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 through 2001 (From Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Aggregations Above Bonneville Dam:																	
Clackamas summer	5.17	0.83	0.94	13.00	88.09	0.73	0.93	28.00	258.24								
Clackamas winter	4.47	0.88	0.94	7.00	35.31	0.76	0.94	23.50	156.84								
Green River winter	4.47	0.90	1.03	14.00	79.60	0.90	1.03	14.00	79.60								
Kalama summer	5.17	0.91	0.94	3.00	16.51	0.77	0.93	21.00	167.87								
Kalama River winter	4.47	0.97	0.97	0.00	0.00	0.90	0.93	3.00	14.12								
Sandy winter	4.47	0.91	0.95	4.00	19.16	0.85	0.95	11.50	62.66								
Toutle winter	4.47	0.88	0.93	6.00	29.75	0.88	0.93	6.00	29.75								
Columbia River Chum Salmon																	
ESU Aggregate	3.61	1.04				1.04											
Aggregations Above Bonneville Dam:																	
Grays River west fork	3.61	1.23				1.23											
Grays River mouth to head	3.61	0.96				0.96											
Hardy Creek	3.61	1.05				1.05											
Crazy Johnson	3.61	1.16				1.16											
Hamilton	3.61	0.92				0.92											
Hamilton Springs	3.61	1.11				1.11											

Table A-4. Needed incremental change from base period survival to achieve 50% likelihood of recovery in 48 years. A "Necessary % Change in Lambda" of, for example, 1.99 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0199 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 9.79 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.0979 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Spring/Summer Chinook																	
Bear Valley/Elk Creeks	4.729	1.02	1.05	3.14	15.75	1.02	1.05	3.14	15.75	1.03	1.05	1.99	9.79	1.03	1.05	1.99	9.79
Imnaha River[1]	4.486	0.89	1.04	16.99	102.14	0.88	1.04	18.61	114.99	0.92	1.04	13.15	74.04	0.91	1.04	15.09	87.87
Johnson Creek	4.351	1.01	1.03	1.70	7.61	1.01	1.03	1.70	7.61	1.03	1.03	0.00	0.00	1.03	1.03	0.00	0.00
Marsh Creek	4.684	0.99	1.07	8.29	45.19	0.99	1.07	8.29	45.19	1.00	1.07	6.70	35.48	1.00	1.07	6.70	35.48
Minam River	4.178	0.98	1.05	7.79	36.83	0.93	1.05	12.79	65.36	1.02	1.05	3.61	15.95	0.97	1.05	8.82	42.33
Poverty Flats	4.221	1.00	1.03	2.61	11.51	0.99	1.03	3.67	16.41	1.02	1.03	0.40	1.69	1.02	1.03	1.31	5.65
Sulphur Creek	4.610	1.04	1.07	2.74	13.26	1.04	1.07	2.74	13.26	1.05	1.07	1.63	7.72	1.05	1.07	1.63	7.72
Snake River Fall Chinook																	
Aggregate	4.137	0.92	1.05	14.07	72.42	0.87	1.05	20.21	114.13								
Upper Columbia River Spring Chinook																	
Methow River - QAR	4.400	0.90	1.06	17.72	105.000	0.90	1.06	17.72	105.000								
Entiat River - QAR	4.320	0.89	1.06	19.00	112.000	0.89	1.06	19.00	112.000								
Wenatchee River - QAR	4.370	0.88	1.10	25.52	170.000	0.88	1.10	25.52	170.000	0.92	1.10	19.14	115.00	0.92	1.10	19.14	115.00
Methow River - CRI	4.250	0.86	1.08	24.74	155.86	0.85	1.08	27.03	176.48	0.89	1.08	20.24	118.90	0.87	1.08	23.62	146.23
Entiat River - CRI	4.210	0.85	1.05	23.43	142.58	0.81	1.05	29.74	199.29	0.89	1.05	18.50	104.36	0.85	1.05	23.85	146.09
Wenatchee River - CRI	4.336	0.80	1.06	32.03	233.64	0.80	1.06	33.26	247.34	0.85	1.06	24.76	160.97	0.84	1.06	26.13	173.66
Upper Columbia River Steelhead																	
Methow - QAR	3.800	0.97	1.08	12.22	55.00	0.81	1.08	33.52	200.00								
Wenatchee/Entiat - QAR	3.800	0.94	1.05	11.26	50.00	0.85	1.04	23.06	120.00								

1 50%, rather than 20%, effectiveness of hatchery-origin natural spawners was applied to the Imnaha index stock..

Table A-5. Needed incremental change from base period survival to achieve 50% likelihood of recovery in 100 years. A "Necessary % Change in Lambda" of, for example, 1.99 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0199 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 9.79 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.0979 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Spring/Summer Chinook																	
Bear Valley/Elk Creeks	4.729	1.02	1.02	0.00	0.00	1.02	1.02	0.00	0.00	1.03	1.02	0.00	0.00	1.03	1.02	0.00	0.00
Imnaha River[1]	4.486	0.89	1.02	14.31	82.17	0.88	1.02	15.89	93.75	0.92	1.02	10.55	56.85	0.91	1.02	12.46	69.31
Johnson Creek	4.351	1.01	1.01	0.00	0.00	1.01	1.01	0.00	0.00	1.03	1.01	0.00	0.00	1.03	1.01	0.00	0.00
Marsh Creek	4.684	0.99	1.03	4.45	22.62	0.99	1.03	4.45	22.62	1.00	1.03	2.92	14.43	1.00	1.03	2.92	14.43
Minam River	4.178	0.98	1.02	4.88	22.03	0.93	1.02	9.74	47.48	1.02	1.02	0.81	3.41	0.97	1.02	5.87	26.93
Poverty Flats	4.221	1.00	1.01	1.07	4.61	0.99	1.01	2.11	9.21	1.02	1.01	0.00	0.00	1.02	1.01	0.00	0.00
Sulphur Creek	4.610	1.04	1.03	0.00	0.00	1.04	1.03	0.00	0.00	1.05	1.03	0.00	0.00	1.05	1.03	0.00	0.00
Snake River Fall Chinook																	
Aggregate	4.137	0.92	1.02	11.21	55.23	0.87	1.02	17.19	92.78								
Upper Columbia River Spring																	
Methow River - QAR	4.400	0.90	1.04	16.39	95.00	0.90	1.04	16.39	95.00								
Entiat River - QAR	4.320	0.89	1.04	17.40	100.00	0.89	1.04	17.40	100.00								
Wenatchee River - QAR	4.370	0.88	1.09	23.89	155.00	0.88	1.09	23.89	155.00	0.93	1.09	17.46	102.00	0.93	1.09	17.46	102.00
Methow River - CRI	4.250	0.86	1.03	19.89	116.20	0.85	1.03	22.10	133.63	0.89	1.03	15.57	84.97	0.87	1.03	18.82	108.07
Entiat River - CRI	4.210	0.85	1.02	19.92	114.84	0.81	1.02	26.05	165.06	0.89	1.02	15.13	80.99	0.85	1.02	20.33	117.95
Wenatchee River - CRI	4.336	0.80	1.03	27.88	190.43	0.80	1.03	29.07	202.35	0.85	1.03	20.83	127.18	0.84	1.03	22.16	138.22
Upper Columbia River																	
Methow - QAR	3.800	0.97	1.08	12.22	55.00	0.81	1.08	33.52	200.00								
Wenatchee/Entiat - QAR	3.800	0.94	1.05	11.26	50.00	0.85	1.04	23.06	120.00								

1 50%, rather than 20%, effectiveness of hatchery-origin natural spawners was applied to the Imnaha index stock..

Table A-6. Needed incremental change from base period survival to achieve lambda = 1.0, for stocks that do not have an interim recovery abundance level. A "Necessary % Change in Lambda" of, for example, 9.65 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0965 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 54.58 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.5458 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Snake River Spring/Summer Chinook																	
Aggregate ESU	4.73	0.91	1.00	9.65	54.58	0.82	1.00	22.26	158.72								
Alturas Lake Creek	4.465	0.75	1.00	34.14	271.19	0.75	1.00	34.14	271.19								
American River	4.465	0.91	1.00	10.10	53.68	0.91	1.00	10.10	53.68								
Big Sheep Creek	4.465	0.88	1.00	13.90	78.81	0.85	1.00	17.36	104.41								
Beaver Creek	4.465	0.95	1.00	4.94	24.05	0.95	1.00	4.94	24.05								
Bushy Fork	4.465	0.98	1.00	2.01	9.28	0.98	1.00	2.01	9.28								
Camas Creek	4.465	0.92	1.00	8.45	43.64	0.92	1.00	8.45	43.64								
Cape Horn Creek	4.465	1.05	1.00	0.00	0.00	1.05	1.00	0.00	0.00								
Catherine Creek	4.465	0.85	1.00	17.85	108.23	0.78	1.00	27.82	199.26								
Catherine Creek N. Fork	4.465	0.92	1.00	8.60	44.57	0.92	1.00	8.60	44.57								
Catherine Creek S. Fork	4.465	0.80	1.00	25.68	177.51	0.80	1.00	25.68	177.51								
Crooked Fork	4.465	1.00	1.00	0.11	0.51	1.00	1.00	0.11	0.51								
Grande Ronde River	4.465	0.84	1.00	19.23	119.35	0.77	1.00	29.22	214.09								
Knapp Creek	4.465	0.89	1.00	12.37	68.31	0.89	1.00	12.37	68.31								
Lake Creek	4.465	1.06	1.00	0.00	0.00	1.06	1.00	0.00	0.00								
Lemhi River	4.465	0.98	1.00	2.50	11.64	0.98	1.00	2.50	11.64								
Lookingglass Creek	4.465	0.79	1.00	25.83	178.94	0.72	1.00	37.97	320.95								
Loon Creek	4.465	1.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00								
Lostine Creek	4.465	0.90	1.00	10.90	58.72	0.87	1.00	14.91	86.00								
Lower Salmon River	4.465	0.92	1.00	9.08	47.43	0.92	1.00	9.08	47.43								
Lower Valley Creek	4.465	0.92	1.00	8.27	42.57	0.92	1.00	8.27	42.57								
Moose Creek	4.465	0.94	1.00	5.94	29.40	0.94	1.00	5.94	29.40								
Newsome Creek	4.465	1.03	1.00	0.00	0.00	1.03	1.00	0.00	0.00								
Red River	4.465	0.91	1.00	9.97	52.85	0.91	1.00	9.97	52.85								
Salmon River E. Fork	4.465	0.94	1.00	6.46	32.25	0.94	1.00	6.46	32.25								
Salmon River S. Fork	4.465	1.06	1.00	0.00	0.00	1.06	1.00	0.00	0.00								
Secesh River	4.465	0.98	1.00	2.44	11.35	0.98	1.00	2.44	11.35								
Selway River	4.465	0.91	1.00	9.43	49.52	0.91	1.00	9.43	49.52								
Sheep Creek	4.465	0.80	1.00	25.13	172.07	0.80	1.00	25.13	172.07								

Table A-6 (continued). Needed incremental change from base period survival to achieve lambda = 1.0, for stocks that do not have an interim recovery abundance level. A "Necessary % Change in Lambda" of, for example, 9.65 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0965 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 54.58 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.5458 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Upper Big Creek	4.465	0.97	1.00	3.33	15.76	0.97	1.00	3.33	15.76								
Upper Salmon River	4.465	0.90	1.00	10.58	56.68	0.90	1.00	10.58	56.68								
Upper Valley Creek	4.465	1.03	1.00	0.00	0.00	1.03	1.00	0.00	0.00								
Wallowa Creek	4.465	0.86	1.00	16.30	96.24	0.86	1.00	16.30	96.24								
Wenaha River	4.465	0.90	1.00	10.73	57.65	0.84	1.00	18.77	115.54								
Whitecap Creek	4.465	0.90	1.00	10.77	57.91	0.90	1.00	10.77	57.91								
Yankee Fork	4.465	0.88	1.00	13.30	74.63	0.88	1.00	13.30	74.63								
Yankee West Fork	4.465	0.99	1.00	1.13	5.16	0.99	1.00	1.13	5.16								
Upper Willamette River Chinook																	
McKenzie River above	4.430	0.99	1.00	1.01	4.55	0.90	1.00	11.11	59.48								
Lower Columbia River																	
Aggregations Above Bonneville Dam:																	
Bear Creek	3.29	0.82	1.00	21.31	88.80	0.73	1.00	37.22	183.20								
Big Creek	3.96	0.93	1.00	7.15	31.46	0.84	1.00	18.70	97.19								
Clatskanie	3.68	0.89	1.00	12.58	54.56	0.80	1.00	25.71	131.85								
Cowlitz Tule	3.56	0.92	1.00	8.24	32.55	0.82	1.00	21.29	98.82								
Elochoman	3.50	0.99	1.00	1.12	3.97	0.88	1.00	13.54	55.96								
Germany	3.68	0.93	1.00	7.36	29.82	0.83	1.00	19.88	94.73								
Gnat	3.74	0.94	1.00	6.66	27.27	0.84	1.00	18.87	90.90								
Grays Tule	3.53	0.85	1.00	17.37	76.00	0.76	1.00	31.65	163.99								
Kalama Spring	3.77	0.85	1.00	18.03	86.80	0.76	1.00	31.43	180.20								
Kalama	3.77	0.99	1.00	1.44	5.53	0.89	1.00	12.96	58.30								
Klaskanine	3.68	0.89	1.00	12.38	53.54	0.80	1.00	25.48	130.31								
Lewis River Bright	3.84	0.99	1.00	1.39	5.42	0.97	1.00	2.71	10.83								
Lewis Spring	3.84	0.91	1.00	10.43	46.36	0.81	1.00	22.73	119.55								
Lewis, E Fork Tule	3.84	0.99	1.00	0.78	3.01	0.99	1.00	0.78	3.01								
Lewis and Clark	3.84	0.54	1.00	83.73	933.74	0.49	1.00	105.63	1493.10								
Mill Fall	3.68	0.81	1.00	23.78	119.05	0.72	1.00	38.22	228.58								

Table A-6 (continued). Needed incremental change from base period survival to achieve lambda = 1.0, for stocks that do not have an interim recovery abundance level. A "Necessary % Change in Lambda" of, for example, 9.65 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0965 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 54.58 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.5458 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Plympton	3.83	0.95	1.00	5.11	21.03	0.86	1.00	16.85	81.54								
Sandy Late	3.68	0.98	1.00	1.76	6.63	0.98	1.00	2.27	8.59								
Skamokawa	3.68	0.82	1.00	21.65	105.46	0.74	1.00	35.84	208.19								
Youngs	3.68	0.94	1.00	6.35	25.37	0.84	1.00	18.75	88.06								
Snake River Steelhead																	
ESU Aggregate	5.168	0.83	1.00	19.81	154.46	0.72	1.00	38.66	441.55								
A-Run Aggregate	5.040	0.85	1.00	17.09	121.47	0.74	1.00	34.94	352.83								
A-Run Pseudopopulation	5.040	0.85	1.00	17.09	121.47	0.74	1.00	34.94	352.83								
B-Run Aggregate	6.490	0.84	1.00	19.68	220.96	0.74	1.00	34.28	577.48								
B-Run Pseudopopulation	6.490	0.84	1.00	19.68	220.96	0.74	1.00	34.28	577.48								
Mid-Columbia River Steelhead																	
ESU Aggregate	5.17	0.84	1.00	18.48	140.28	0.77	1.00	29.87	286.15								
Deschutes River summer	5.169	0.84	1.00	19.07	146.47	0.77	1.00	30.55	296.73								
Warm Springs NFH summer	5.169	0.91	1.00	10.27	65.76	0.91	1.00	10.27	65.76								
Umatilla River summer	5.169	0.90	1.00	11.29	73.82	0.90	1.00	10.67	68.91								
Yakima River summer	5.169	1.04	1.00	0.00	0.00	1.01	1.00	0.00	0.00								
Upper Willamette River Steelhead																	
ESU Aggregate	4.08	0.92	1.00	8.11	37.46	0.88	1.00	13.77	69.25								
Mollala	4.080	0.91	1.00	9.60	45.36	0.84	1.00	19.67	108.05								
N Santiam River	4.080	0.92	1.00	8.89	41.55	0.89	1.00	11.91	58.27								
S Santiam	4.080	0.94	1.00	6.63	29.94	0.87	1.00	15.13	77.71								
Calapooia	4.080	0.93	1.00	7.80	35.87	0.93	1.00	7.80	35.87								

Table A-6 (continued). Needed incremental change from base period survival to achieve lambda = 1.0, for stocks that do not have an interim recovery abundance level. A "Necessary % Change in Lambda" of, for example, 9.65 means that the median annual population growth rate ("Estimated Lambda") must be multiplied by 1.0965 to meet the recovery criterion. A "Necessary % Change in Survival" of, for example, 54.58 means that the average 1980-to-most-recent-year egg-to-adult survival rate rate, or any component life-stage survival rate, must be multiplied by 1.5458 to meet the recovery criterion.

		Lambda Calculated From 1980 to Most Recent Completed Year								Lambda Calculated From 1980 Through 2001 (Based on Jack Returns)							
		20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners				20% Historical Effectiveness of Hatchery Spawners				80% Historical Effectiveness of Hatchery Spawners			
	Mean Gen. Time	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival	Estimated Lambda	Lambda Needed to Meet Criterion	Necessary % Change in Lambda	Necessary % Change in Survival
Lower Columbia River Steelhead																	
ESU Aggregate	4.47	0.91	1.00	9.98	52.99	0.80	1.00	24.97	170.82								
Aggregations Above Bonneville Dam:																	
Clackamas summer	5.17	0.83	1.00	20.42	161.32	0.73	1.00	37.09	410.77								
Clackamas winter	4.47	0.88	1.00	13.41	75.46	0.76	1.00	31.75	242.95								
Green River winter	4.47	0.90	1.00	10.73	57.68	0.90	1.00	10.73	57.68								
Kalama summer	5.17	0.91	1.00	9.83	62.34	0.77	1.00	30.37	293.92								
Kalama River winter	4.47	0.97	1.00	2.70	12.65	0.90	1.00	10.71	57.59								
Sandy winter	4.47	0.91	1.00	9.32	48.93	0.85	1.00	17.82	108.07								
Toutle winter	4.47	0.88	1.00	14.25	81.40	0.88	1.00	14.25	81.40								
Columbia River Chum Salmon																	
ESU Aggregate	3.61	1.04	1.00	0.00	0.00	1.04	1.00	0.00	0.00								
Aggregations Above Bonneville Dam:																	
Grays River west fork	3.61	1.23	1.00	0.00	0.00	1.23	1.00	0.00	0.00								
Grays River mouth to head	3.61	0.96	1.00	4.60	17.61	0.96	1.00	4.60	17.61								
Hardy Creek	3.61	1.05	1.00	0.00	0.00	1.05	1.00	0.00	0.00								
Crazy Johnson	3.61	1.16	1.00	0.00	0.00	1.16	1.00	0.00	0.00								
Hamilton	3.61	0.92	1.00	8.81	35.64	0.92	1.00	8.81	35.64								
Hamilton Springs	3.61	1.11	1.00	0.00	0.00	1.11	1.00	0.00	0.00								

numbers were estimated from information in the digital appendices to McClure et al. (2000c). The necessary percent improvement in population growth rate to achieve recovery goals in the allotted time was then calculated using the ratio of the needed growth rate to the current growth rate. This method assumes that population growth is density-independent (see discussion in Section A.3.1).

For the spawning aggregations comprising all other ESUs, as well as for the spawning aggregations that are not defined as index stocks for the SR spring/summer chinook ESU, an alternative recovery indicator criterion was evaluated. Because interim recovery abundance levels have not yet been defined for these stocks, this analysis determines the change in survival necessary to achieve an increasing population growth rate (λ>1.0) . Equation 4 defines the calculation.

(4) $$\Delta\lambda > 1.0 \div \lambda$$

in which λ refers to the current estimate (1980 through most recent available year).

All CRI-based estimates of the multiplicative change in annual population growth rate ($\Delta\lambda$) were converted to a multiplicative change in per-generation (egg-to-adult spawner) survival rate (ΔS) according to Equation 1 using mean generation times (in years) listed in Tables A2 to A6. For example, if the base λ must be multiplied by 1.05, and the average generation time of the stock is 4.56 years, the 1.05 change must be applied to the annual survival rate for each of those 4.56 years. To determine the necessary change over the lifetime of a salmon, the base period egg-to-spawner survival rate (or any survival rate contributing to this) must be multiplied by $1.05^{4.56}$, which is equal to 1.25.

<u>QAR Estimates</u> The QAR estimates of survival changes necessary to meet survival and recovery criteria are from Cooney (2000) and various personal communications with T. Cooney (NMFS). QAR estimates applied only to UCR steelhead and UCR spring chinook. QAR estimates of the needed change were sometimes reported only as changes in per-generation survival. To generate $\Delta\lambda$ in Tables C2 to C6 for QAR estimates, Equation 1 was rearranged as follows:

(5) $$\Delta\lambda = \Delta S^{(1/\text{Mean Generation Time})}$$

Methods used to generate the QAR estimates are described in Cooney (2000).

A.4.2 Key Assumptions Influencing Estimates of Current Population Trend and Change Necessary to Meet Survival and Recovery Indicator Criteria

NMFS considered three sets of alternative assumptions that influenced the current trend estimate and estimates of the survival change necessary to meet survival and recovery indicator criteria. The first is the historical effectiveness of hatchery-origin natural spawners for populations in which both wild- and hatchery-origin spawners have contributed to production. In these mixed populations, the productivity of the wild-origin spawners is unknown. If the reproductive success of hatchery-origin spawners has been high during the base period, then the productivity of natural-origin spawners is lower than would be predicted from the mixed stock returns. In this situation, a large improvement in the survival rate of natural-origin fish may be necessary to reduce risk to the levels described in Table A-1. Conversely, if the effectiveness of hatchery-origin spawners has been low during the base period, productivity of natural-origin spawners is higher than in the previous case, and a smaller survival improvement is needed.

The effectiveness of hatchery-origin natural spawners during the base period could have ranged from 0% to 100%. Based on a review of pertinent literature, NMFS considers a range of between 20% to 80% effectiveness to capture a large fraction of realistic scenarios (Waples 2000). While it may be possible to further narrow this range if there is an understanding of the specific characteristics of the hatchery-produced spawners (e.g., locally derived, non-domesticated versus non-native or domesticated hatchery populations), NMFS applied the full range to all but one stock evaluated in the biological opinion. NMFS applied a range of 50% to 80% hatchery-origin spawner effectiveness to the Imnaha River SR spring/summer chinook index stock, based on information reviewed in Section 6.3.1.5 of the biological opinion.

The second assumption that affects this analysis is the selection of the base period. Extinction risk depends on the trend during the base period, variability in the trend, and current population level. Results for some populations can vary drastically, depending on choice of the starting year of the time series (Waples et al. 1991). For this reason, and because of assumptions of the Dennis et al. (1991) extinction risk model regarding time series characteristics (McClure et al. 2000c), the relevant time period must be chosen carefully. NMFS considers the period between 1980 and the present the most appropriate for all ESUs considered in this biological opinion (Schiewe 2000) because it most closely resembles current operation and configuration of the hydrosystem, including upstream storage. This includes the doubling of water storage capacity in the 1970s, which is likely to have affected the freshwater plume and estuarine conditions.

While NMFS did not consider alternative starting years in this analysis, it did consider alternative definitions of “the present” for two ESUs. For all ESUs, the primary analysis used the most recently available return year, which ranged from 1996 for SR fall chinook to 1999 for SR spring/summer chinook (digital appendices, McClure et al. 2000c). For UCR spring chinook and SR spring/summer chinook (moderate projection category; Cooney 2000, McClure et al. 2000b), NMFS also included preliminary 2000 return estimates and projected 2001 returns from 2000 jack counts. Because survival of fish returning in 2000 and projected to return in 2001 is higher than that occurring during most other years of the time series, addition of these return years results in a lower estimate of extinction risk and a lower needed change in survival.

The third factor influencing these results was use of CRI or QAR analysis for UCR steelhead and UCR spring chinook estimates. QAR estimates of needed survival change are consistently lower than those of CRI for the three UCR spring chinook populations. The QAR Methow and Wenatchee/Entiat UCR steelhead estimates are also lower than the CRI estimate for the aggregate UCR steelhead ESU. NMFS does not understand the nature of these discrepancies at present and is working to resolve them. Until this occurs, NMFS includes both analytical approaches to represent a reasonable range of results for the UCR ESUs.

To summarize, the biological opinion included two alternatives for each of three key assumptions influencing the range of trend estimates and the estimate of the survival change needed to meet the survival and recovery indicator criteria. Table A-7 displays each alternative and the ESUs to which it applies.

Table A-7. Alternative assumptions for estimation of the base period trend and survival changes necessary to meet survival and recovery indicator criteria.

Assumption	Alternatives Included	ESUs to Which Alternatives Were Applied
Effectiveness of Hatchery-Origin Natural Spawners During Base Period	1. 20%, relative to wild-origin natural spawners (except for 50% for Imnaha River SR spring/summer chinook index stock) 2. 80%, relative to wild-origin natural spawners	All 12 ESUs included in the quantitative analysis.
Base Period (Years Included in Estimate of Annual Population Growth Rate and Per-Generation Survival Rate)	1. 1980 - most recent return year for which spawner counts are available (no later than 1999) 2. 1980 - projected 2001 spawner counts	First alternative applied to all 12 ESUs. Both alternatives are applied only to UCR spring chinook and SR spring/summer chinook.
Analytical Method	1. CRI 2. QAR	First alternative applied to all 12 ESUs. Both alternatives are applied only to UCR spring chinook and UCR steelhead.

A.5 PROPORTIONAL SURVIVAL CHANGE ASSOCIATED WITH THE PROPOSED ACTION, RPA, AND BREACHING

The third step of the analysis is to estimate the change in survival rates associated with proposed actions and with changes in other life stages anticipated in the Basinwide Recovery Strategy. The necessary improvements in population growth rate described in Section A.4 are based on the assumption that average life-stage survival rates influencing adult returns from 1980 to the most recent year (base period) will continue indefinitely into the future. However, certain life-stage survival rates associated with current conditions and proposed actions represent an improvement from the average survival rate that influenced adult returns during the base period. In this section, NMFS first identifies life stages for which current or expected survival represents a quantifiable change from average survival during the base period. NMFS then estimates average base period survival rates for these life stages and current and future expected survival rates. NMFS then calculates the proportional survival change represented by the actions.

This analysis applies only to life-stages and actions for which enough information exists to quantify survival rates. These life stages are restricted to juvenile and adult mainstem passage survival rates associated with FCRPS actions and survival rate changes associated with changes in harvest rates. In nearly all cases, NMFS is unable to quantitatively estimate survival rates and/or survival rate changes associated with habitat and hatchery management actions. The one exception is the implicit estimate of the effects of habitat and hatchery actions when the Mid-Columbia Habitat Conservation Plan (HCP) is implemented. These other actions and life-stage survival changes are evaluated qualitatively in the biological opinion and are not addressed in this appendix. Additionally, this analysis does not address non-quantifiable effects of the FCRPS, such as effects on spawning success and incubation and rearing survival for mainstem-spawning ESUs.

A.5.1 Snake River Spring/Summer Chinook Salmon

The SR spring/summer chinook salmon population trends estimated in Section A.4 were derived from 1980-to-1999 adult returns. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem represents an improvement from the average juvenile passage survival rate influencing 1980-to-1999 adult returns. That is because many structural and operational modifications to the hydrosystem have been implemented since 1980. A short review of these modifications and their impacts on juvenile passage survival is included in Section 6.3.1.3 of the biological opinion. Additional juvenile passage survival improvements are anticipated under the hydrosystem component of the reasonable and prudent alternative (RPA), and survival rate changes are also expected if four Snake River dams are breached. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average 1980-to-1999 adult survival rate. However, NMFS estimates that the adult survival rate associated with the RPA and with breaching will be an improvement over the 1980-to-1999 adult survival rate. The following sections review the methods and estimates for these juvenile and adult passage survival rate changes. Harvest rate changes have been, and are expected to continue to be, relatively minor for this ESU, so are not included in this analysis. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-8 provides an overview of the assumptions and life stages addressed in this analysis. The assumptions and life stages are discussed in more detail in the following sections.

A.5.1.1 Survival Rate Change Associated With the Proposed Action

Juvenile Passage Survival NMFS used two methods to estimate the proportional change in juvenile survival from that experienced on average by adults returning from 1980 to 1999 to that associated with the proposed action, which is essentially a continuation of the current juvenile survival rate. The first method compared PATH estimates of juvenile survival during 1980 to 1992 (retrospective scenario in Marmorek et al. 1998) to PATH estimates of 1995 FCRPS Biological Opinion operations applied to the same water conditions (scenario A2 of Marmorek et al. 1998). The purpose was to evaluate historical survival versus an approximation of current juvenile survival under a 13-year range of water conditions. NMFS applied the approach in response to comments by agencies and organizations that the method used in the July 27 Draft

Biological Opinion evaluated the change from historical to current operations under too narrow a range of water years for current operations, which led to overly optimistic results.

Table A-8. Key assumptions affecting the range of Snake River spring/summer chinook salmon survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct LGR-BON Juvenile Passage Survival	Method 1: PATH passage models used for both base period and proposed action estimates Method 2: Combination of PATH and SIMPAS for base period; SIMPAS for proposed action	Method 1: PATH passage models used for both base period and RPA estimates Method 2: Combination of PATH and SIMPAS for base period; SIMPAS for RPA	**Base**: Method 1 and Method 2, as described for other actions **Breach**: One estimate, derived from LGR-MCN free-flowing reach survival and MCN-BON from SIMPAS RPA estimate
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D)	Average of D=0.65 and D=0.75, for both base and proposed action, so does not affect estimate	Average of D=0.65 and D=0.75, for both base and RPA, so does not affect estimate	**Base:** Average of D=0.65 and D=0.75 **Breach**: No transportation, so D not relevant. All fish have equivalent post-BON survival, which is functionally equivalent to D=1.0.
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value (0% to 74%)	Assumed constant for base and RPA, so does not affect estimate, regardless of value (0% to 74%)	**Approach 1**: Assumed constant for base and breach, so does not affect estimate, regardless of value (0% to 74%) **Approach 2:** High in base period (71% to 74%); half that after breaching 4 of 8 dams (36% to 37%) **Approach 3:** High in base period (71% to 74%); 0% after breaching 4 dams
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	Same survival improvement as base to RPA. Delayed mortality, if any, identical in base and breach, so does not affect estimate.
Harvest	Similar in base and current/future, so no change included in calculations.	Similar in base and current/future, so no change included in calculations.	Similar in base and current/future, so no change included in calculations.
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion

The 1980 juvenile passage survival estimate corresponds to the first juvenile migration year that fully contributes to adult returns in the first pair of 5-year running sums used to calculate lambda (McClure et al. 2000c, Holmes in review). The first two running sums represent weighted sums of 1980 through 1984 returns and 1981 through 1985 returns. The 1992 migration year represents the last year for which PATH model estimates are available. The survival rate used in NMFS' comparison included estimates of direct survival to below Bonneville Dam from both of PATH's alternative passage models (FLUSH and CRiSP; Marmorek et al. 1998; data files in allpmrun.zip, obtained from C. Peters June 18, 1999). NMFS used the PATH retrospective results for a set of passage assumptions considered closest to mean PATH results (C. Peters, ESSA, pers. comm., June 1999) and averaged the estimates from the two alternative PATH passage models.

NMFS included differential post-Bonneville survival (D=0.63 to 0.73; Section 6.2.3.3) in addition to the direct survival estimates because, even though NMFS finds no evidence that D changed during the 1980-to-1999 period, the proportion of fish transported has changed over time. Because the proportion of transported fish surviving to Bonneville is multiplied by D, D has a significant impact on survival. On the other hand, delayed mortality of nontransported fish had no effect on the proportional change in survival, so was not relevant to this analysis.

The expected juvenile passage survival change ranged from 27% to 38%, depending on passage model and D assumption, and averaged 32% (1.39 times the average historical survival rate) across all assumptions (Table A-9).

The second method represented a modification of the approach used in the July 27, 2000, Draft Biological Opinion. In this case, NMFS defined average juvenile passage survival during the historical period using PATH passage model estimates for 1980 to 1992, coupled with Simple Passage Model (SIMPAS) estimates for 1994 to 1997. The 1997 migration year was included because it was the last migration year contributing to the 1999 adult returns in NMFS' 1980-to-1999 risk assessment. An estimate for 1993 is not available from either passage modeling system. The average of all 17 years was the estimate corresponding to NMFS' 1980-to-1999 risk assessment. NMFS defined current operations corresponding to effects of the proposed action as the 1994-to-1999 average SIMPAS estimates. Section 6.2 of the biological opinion describes the rationale for equally weighting each year when calculating the average. This second method resulted in expected survival improvements ranging from 12% to 35%, depending upon passage model and D assumption, and averaged 24% (1.24 times the average historical survival rate) across all assumptions (Table A-9).

The July 27, 2000, Draft Biological Opinion included a method similar to this second approach, since it also combined SIMPAS and PATH estimates of juvenile survival to evaluate the change in juvenile survival. Several agencies and organizations criticized that approach, claiming that some intrinsic difference between PATH and SIMPAS passage models overestimates the survival improvement associated with the proposed action. The difference cited most frequently was the treatment of reservoir survival in each passage model. However, both of PATH's passage models provide fairly close fits to NMFS' 1994-to-1996, PIT-tag reach survival

Table A-9. Estimates of proportional change in SR spring/summer chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
Base to Current		
a. Juvenile Passage Survival		
Base Method 1 = average PATH 1980-1992 migration year retrospective juvenile survival with D=.63 and 0.73.		
CRiSP .63	0.391	
CRiSP .73	0.440	
FLUSH .63	0.440	
FLUSH .73	0.503	
Current Method 1 = average PATH A2 1977-1992 WY juvenile survival with D=.63 and 0.73.		
CRiSP .63	0.532	1.362
CRiSP .73	0.606	1.379
FLUSH .63	0.558	1.269
FLUSH .73	0.646	1.284
average:		**1.323**
Base Method 2 = PATH 1980-92 + SIMPAS 1994-97 with D=0.63,0.73		
CRiSP .63 + SIMPAS	0.423	
CRiSP .73 + SIMPAS	0.460	
FLUSH .63 + SIMPAS	0.460	
FLUSH .73 + SIMPAS	0.509	
Current Method 2 = average SIMPAS 1994-99 juvenile survival with D=0.63,0.73		
SIMPAS	0.571	1.351
		1.241
		1.241
		1.122
average:		**1.239**
Current to RPA		
a. Juvenile Passage Survival		
Current = SIMPAS including D=0.63-0.73	0.571	
RPA = SIMPAS RPA including D=0.63-0.73	0.576	1.009
b. Adult Passage Survival		
Current =	0.825	
RPA =	0.855	
		1.037
c. Combined Juvenile and adult change from RPA		1.046
Combined Base-to-Current and Current -to-RPA Change:		
PATH/PATH Base:Current Hydro		**1.384**
PATH/SIMPAS Base:Current Hydro		**1.296**

Table A-9 (continued). Estimates of proportional change in SR spring/summer chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
Base to Breach		
a. Juvenile Passage Survival		
Assumption #1: No Change in EM Between Base and Breach		
(Same proportional change, whether EM high or low)		
Base Method 1 = average PATH 1980-1992 retrospective juvenile survival with D=.63 and 0.73 and EM = 0.709,.743		
CRiSP .63	0.114	
CRiSP .73	0.113	
FLUSH .63	0.128	
FLUSH .73	0.129	
Base Method 2 = PATH 1980-92 + SIMPAS 1994-97		
(Matches better with 1980-99 adult return in CRI analysis)		
CRiSP .63 + SIMPAS	0.123	
CRiSP .73 + SIMPAS	0.118	
FLUSH .63 + SIMPAS	0.134	
FLUSH .73 + SIMPAS	0.131	
Breach=Natural For Snake*MCN-BON SIMPAS RPA*(1-avg [.709,.743])	0.168	
PATH/PATH:		1.392
PATH/SIMPAS:		1.329
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached		
Breach=Natural For Snake and (1-(0.5*.726))*MCN-BON SIMPAS RPA	0.390	
PATH/PATH:		3.237
PATH/SIMPAS:		3.090
Assumption #3: EM is high in base and all goes away when 4 dams breached		
Breach=Natural For Snake*MCN-BON SIMPAS RPA	0.612	
PATH/PATH:		5.081
PATH/SIMPAS:		4.851
b. Adult Passage Survival (Breach expected identical to RPA)		
Base/Current =	0.825	
RPA/Breach =	0.855	1.037
c. Combined adult and Juvenile Survival		
Assumption #1: No Change in EM Between Base and Breach		
PATH/PATH:		**1.443**
PATH/SIMPAS:		**1.378**
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached		
PATH/PATH:		**3.356**
PATH/SIMPAS:		**3.204**
Assumption #3: EM is high in base and all goes away when 4 dams breached		
PATH/PATH:		**5.268**
PATH/SIMPAS:		**5.029**

estimates (Marmorek and Peters 1998), and the SIMPAS model is calibrated directly to those and to the 1997-to-1999 reach survival estimates (Appendix D). Additionally, both the structure and parameters of the dam passage components of the SIMPAS model are very similar to those used in PATH (Appendix D). The main difference is that some of the parameter estimates used in SIMPAS reflect new information obtained since the PATH models were completed (Appendix D). Ideally, NMFS would compare PATH and SIMPAS estimates for the same years and actions to test the assumption that SIMPAS provides higher estimates of survival than PATH models. While this was possible for SR fall chinook results (see Section A.5.2), there are no years for which both PATH and SIMPAS SR spring/summer chinook estimates exist. However, it is unlikely that significant discrepancies between PATH and SIMPAS exist because of the similar structure, similar fit to PIT-tag reach survival estimates, and because both the PATH-only and combined PATH and SIMPAS methods included in this analysis yield similar results. Also, because the method using both PATH and SIMPAS yields a lower estimate of the survival change than does the exclusive use of PATH estimates, this approach does not produce optimistic results compared with PATH.

A.5.1.2 Survival Rate Change Associated With the RPA

Juvenile and Adult Passage Survival. Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival beyond the current level associated with the proposed action. NMFS estimates that adult survival will increase from the recent average (82.5%) to 85.5% after implementation of the RPA (Table 9.7-5). This represents a proportional survival increase of 3.7% (Table A-9). NMFS estimates that the hydrosystem component of the RPA will increase juvenile survival to below Bonneville Dam, including differential post-Bonneville survival of transported fish (D=0.63 to 0.73), by approximately 1% (Table 9.7-5; Table A-9). The juvenile survival change is based on a comparison of SIMPAS model results for operations associated with the proposed action and RPA, given 1994 to 1999 water conditions. The product of the proportional survival improvements associated with the current conditions (Section A.5.1.1) and the RPA results in an expected survival improvement of 30% to 38% (1.30 to 1.38 times the average 1980-to-1999 survival rate; Table A-9).

A.5.1.3 Survival Rate Change Associated With Breaching Four Snake River Dams

Overview of Alternative Delayed Mortality Assumptions. A key uncertainty associated with dam breaching is the effect that it will have on survival below Bonneville Dam (e.g., Marmorek and Peters 1998, Peters et al. 1999, Kareiva et al. 2000). Although it is likely that some actions called for by the RPA will improve fish condition and survival below Bonneville Dam, NMFS conservatively assumed that neither the proposed action or RPA would change the post-Bonneville survival of nontransported fish. That is, NMFS considered both the differential survival of transported fish (compared to nontransported fish, D) and the post-Bonneville delayed mortality of nontransported fish (EM) to be unchanged from the 1980 to 1999 period to the future under the proposed action and RPA.

In contrast, NMFS considered three alternatives for future post-Bonneville survival after breaching four Snake River dams. In each alternative, the differential post-Bonneville survival of transported fish is eliminated following breaching because NMFS assumes that transportation would cease. The alternatives apply different assumptions regarding the potential change in delayed mortality of nontransported fish following breaching.

In one alternative, NMFS assumed that delayed mortality of nontransported fish does not change after four Snake River dams are breached. With this alternative, the current estimate of EM is not important, since the calculated change in survival resulting from breaching will be the same whether EM is believed to be 0% or 74%. This alternative corresponds to two of the three PATH extra mortality hypotheses, which ascribe this mortality to causes other than the hydrosystem (Section 6.2.3.3 of the biological opinion).

In the second alternative, NMFS assumes that average 1980-to-1999 EM is between 71% (when couple with D=0.73) and 74% (when coupled with D=0.63). This represents the PATH estimate of hydrosystem-caused, post-Bonneville mortality, when all extra mortality is believed to be caused by the hydrosystem. The estimate of 71% to 74% delayed mortality of nontransported fish represents the upper end of the range NMFS considered in this analysis (Section 6.2.3.3 of the biological opinion). This second alternative assumes that approximately half of this mortality is eliminated when four of the eight Snake River dams are breached, which corresponds to PATH's hydrosystem hypothesis (Marmorek and Peters 1998; Wilson 2000).

The third alternative is identical to the second, except that it assumes that 100% of the delayed mortality of nontransported fish is eliminated. This assumption was included in the July 27 Draft Biological Opinion and incorrectly ascribed to the PATH hydrosystem hypothesis (Wilson 2000). NMFS retains it because several agencies and organizations that commented on the July 27, 2000, Draft Biological Opinion expressed their belief that this is the most likely assumption. Because all of these assumptions are essentially beliefs, inclusion of the full range of beliefs demonstrates the range of possible outcomes after breaching.

Details of the methods and results for each approach follow.

<u>No Change in Delayed Mortality of Nontransported Juveniles After Breaching</u>

NMFS estimated average juvenile passage survival to Bonneville Dam during the base period using the same two approaches and data sets described in Section A.5.1.1 for the change from base to current survival, with one exception. NMFS included differential post-Bonneville survival of transported fish (D=0.63 to D=0.73), as described above. When EM is assumed not to change from that which may have occurred during the base period to that which may occur following breaching, the results are insensitive to assumptions regarding the magnitude of EM. However, to facilitate comparison with the other two EM change approaches, NMFS evaluated a high level of nontransport, delayed mortality during both the 1980-1999 period and following breaching. NMFS has not estimated EM, but assumes that it could range from near zero to the highest rate estimated by PATH (Marmorek et al. 1998). The highest PATH estimate that corresponds to D=0.63 is EM=0.709, and the highest PATH estimate that corresponds to D=0.73 is EM=0.743. By highest PATH estimate, NMFS means an estimate that assumes that the hydrosystem is responsible for all extra mortality (Marmorek et al. 1998) that cannot be explained by PATH's productivity functions, estimates of year-to-year changes in productivity common to several stocks, and estimates of direct survival.

PATH did not actually estimate EM that corresponds to NMFS' D estimates. The EM estimates were derived from PATH total mortality estimates according to the following equation:

(6) EM = 1 - {[exp-(PATH "m"- PATH "M")] ÷ [(D * PATH "Pbt") + (1- PATH "Pbt")]}

in which PATH "m" is the absolute value of the natural logarithm of total mortality that cannot be explained by PATH's productivity functions or assessment of common changes in annual productivity. PATH "M" is the absolute value of the natural log of total direct mortality of juveniles through the hydrosystem. PATH "Pbt" is the proportion of juveniles alive below Bonneville Dam that arrived via transportation. NMFS applied PATH's average FLUSH and CRiSP passage model estimates for these terms and solved for EM using NMFS' estimates of D.

NMFS estimated a range of 11% to 13% juvenile survival during the base period (Table A-9) based on the PATH direct survival estimates described above, coupled with D of 63% to 73% and EM of 71% to 74%.

NMFS evaluated expected juvenile survival from breaching following the transitional period described in Sections 9.7.3.1.1 and 9.7.3.1.2. After a natural channel configuration has developed in the 210-km reach and riparian vegetation has become established, NMFS expects that juvenile survival rates will approximate the rates observed in free-flowing reaches above the head of Lower Granite pool. Estimates of survival from the Salmon River trap at Whitebird to Lower Granite Dam are available for wild spring chinook salmon during 1966 through 1968 (Raymond 1979) and for wild spring/chinook salmon and steelhead during 1993 through 1999 (Smith et al. 1998; Hockersmith et al. 1999; Smith et al. 2000a,b). The estimates for both periods include survival through Lower Granite Reservoir. Those for the recent period also include survival past Lower Granite Dam. Using the methods described in Annex 1 of this appendix to factor out the reservoir and dam mortality, NMFS calculated an average per-km survival rate through the free-flowing stretch of 0.999689614 per km for spring chinook. Interannual variation was high (Annex 1). The average per-km survival rate estimate can be expanded to survival through the entire 210-km reach (0.999689614^{210}) , resulting in a mean reach survival of 92.2% for SR spring/summer chinook salmon (Table 9.7-20 of the biological opinion).

The estimates of survival through the breached section of the Snake River were multiplied by estimates of survival through the four lower Columbia River projects under the RPA to derive an estimate of system survival after the drawdown transition period. SIMPAS estimates of SR spring/summer chinook survival through the four lower Columbia River projects are described in Table 9.7-1 of the biological opinion. In-river survival from McNary pool to Bonneville dam averaged 66.4% (Table 9.7-20 of the biological opinion). When survival through the free-flowing reach in the lower Snake River was combined with survival through the impounded reach in the lower Columbia River, system survival of SR spring/summer chinook salmon averaged 61.2% (Table 9.7-20 of the biological opinion). When the 70% to 74% delayed mortality assumption is applied to the survival at Bonneville, 16.8% juvenile survival is expected after breaching (Table A-9). This represents a 33% to 39% proportional change in juvenile passage survival (Table A-9). Again, an identical proportional change is calculated if NMFS assumes EM = 0 instead of EM = 71% to 74%, because EM was assumed to be constant in both the base period and following breaching.

Adult passage survival during the 1980-to-1999 period was 82.5% (Table 9.7-2 of the biological opinion). Expected survival following breaching is 85.5% (Section 9.7.3.1.4 of the biological opinion). This represents a 3.7% proportional change in adult survival (Table A-9).

When the juvenile and adult survival improvements are combined, the overall effect of breaching four Snake River dams is a 38% to 44% proportional improvement (1.38 to 1.44 times average 1980-to-1999 survival; Table A-9).

<u>Delayed Mortality of Nontransported Juveniles is Reduced by Half After Breaching</u>

All aspects of this approach were identical to the first, except for the level of delayed mortality applied to juvenile survival following breaching. Only half of the delayed mortality estimate was applied in this approach, resulting in 39% juvenile survival following breaching (Table A-9). This represents a 209% to 224% proportional change in juvenile passage survival following breaching. When this juvenile survival change is combined with the adult survival change described above, the result is a 220% to 236% proportional survival improvement (3.20 to 3.36 times average 1980-to-1999 survival) following breaching (Table A-9).

<u>Delayed Mortality of Nontransported Juveniles Is Eliminated After Breaching</u>

All aspects of this approach were identical to the first, except that no delayed mortality was applied to the estimate of juvenile survival following breaching. This resulted in 61% juvenile survival following breaching (Table A-9). A 403% to 427% proportional survival improvement (5.03 to 5.27 times average 1980-to-1999 survival) is associated with breaching under this assumption regarding delayed mortality (Table A-9).

A.5.2 Snake River Fall Chinook Salmon

The SR fall chinook population trends estimated in Section A.4 were derived from 1980-to-1996 adult returns. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem and under the RPA represents an improvement from the average juvenile passage survival rate influencing 1980-to-1996 adult returns. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average 1980-to-1996 adult survival rate. However, NMFS estimates that the adult survival rate associated with the RPA and with breaching will be an improvement from the 1980-to-1996 adult survival rate. Current and expected future harvest rates are lower than the average harvest rates affecting 1980-to-1996 returning adults, which also results in increased survival. The following sections review the methods and estimates for these juvenile and adult survival rate changes. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-10 provides an overview of the assumptions and life stages addressed in this analysis, which are discussed in more detail in the following sections.

Table A-10. Key assumptions affecting the range of Snake River fall chinook salmon survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct LGR-BON Juvenile Passage Survival	Method 1: PATH passage models used for both base period and proposed action estimates Method 2: Combination of PATH and SIMPAS for base period; SIMPAS for proposed action	Method 1: PATH passage models used for both base period and RPA estimates Method 2: Combination of PATH and SIMPAS for base period; SIMPAS for RPA	**Base**: Method 1 and Method 2, as described for other actions **Breach**: Two alternative estimates for LGR-MCN free-flowing reach survival (Breach Method A and Breach Method B), each coupled with one MCN-BON estimate from SIMPAS (RPA)
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D)	Assumed PATH D=0.24, for both base and proposed action, so does not affect estimate	Assumed PATH D=0.24, for both base and proposed action, so does not affect estimate	**Base:** Assumed PATH D=0.24, for both base and proposed action, so does not affect estimate **Breach**: No transportation, so D not relevant. All fish have equivalent post-BON survival, which is functionally equivalent to D=1.0.
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value (0% to 19%)	Assumed constant for base and RPA, so does not affect estimate, regardless of value (0% to 19%)	**Approach 1**: Assumed constant for base and breach, so does not affect estimate, regardless of value (0% to 19%) **Approach 2:** High in base period (19%); half that after breaching 4 of 8 dams (10%) **Approach 3:** High in base period (19%); 0% after breaching 4 dams
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	Same survival improvement as base to RPA. Delayed mortality, if any, identical in base and breach, so does not affect estimate.
Harvest	PSC Method: Base ocean and in-river harvest estimated from PSC model. Current is 70% of 88-92 average from same model. PATH Method: Same as above, except used PATH harvest rate estimates	Identical to approaches described for proposed action.	Identical to approaches described for proposed action.
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion

A.5.2.1 Survival Rate Change Associated With the Proposed Action

Juvenile Passage Survival. The juvenile SR fall chinook salmon survival rate associated with the proposed action is an improvement over the average survival rate influencing 1980-to-1996 adult returns. This is because of the many structural and operational modifications to the hydrosystem since 1980 (Section 6.3.1.3). NMFS used two methods to estimate the proportional change in juvenile survival from that experienced on average by adults returning from 1980 to 1996 to that associated with the proposed action.

The first method compared PATH estimates of juvenile survival for the 1980-to-1992 migration years (retrospective scenario in Marmorek et al. 1998) with PATH estimates of 1995 FCRPS Biological Opinion operations applied to the same water conditions (scenario A2 of Marmorek et al. 1998). The rationale and general method were identical to those defining the first method for SR spring/summer chinook salmon (Section 6.3.1.3). However, NMFS included an estimate of differential delayed mortality specific to SR fall chinook salmon (D = 0.24, Section 6.2.3.3). NMFS has not estimated D for SR fall chinook salmon. As described in Section 6.2.3.3 of the Draft Biological Opinion, there is great uncertainty regarding differential post-Bonneville survival of this ESU. Because this species has not been the subject of formal transportation studies, the scientific justification for any given estimate of D is weaker than for SR spring/summer chinook salmon or steelhead. NMFS (2000) reviewed the range of alternative assumptions Peters et al. (1999) used to estimate D for this species: application of returns of transported and nontransported fish PIT-tagged during the 1995 outmigration, application of transport studies from McNary Dam (i.e., based on Hanford Reach fall chinook) to Snake River fall chinook, and comparisons of different assumptions about D and other values in relation to the best fit of a life-cycle model to the observed recruit-per-spawner data. The estimates of D derived using these alternative methods ranged from approximately 0.05 to more than 1.0. NMFS (2000b) reviewed these methods and noted that each had inherent strengths and weaknesses. For purposes of the July 27, 2000, Draft Biological Opinion, NMFS considered the PATH PIT-tag method more consistent with methods it used to estimate spring/summer chinook and steelhead Ds than with either of the other PATH approaches. Using this method, PATH estimated D=0.24, with very wide statistical confidence limits. NMFS concluded that this represents the best SR fall chinook D-estimate currently available and applied it as a point estimate in the fall chinook analysis.

Direct passage survival terms were averages from PATH (Peters et al.1999; data files in newfall.zip, obtained from C. Peters, October 5, 1999). NMFS used the PATH retrospective results for a set of passage assumptions considered closest to mean PATH results (C. Peters, ESSA, pers. comm., October 1999) and averaged the estimates from the two alternative PATH passage models (FLUSH and CRiSP). The expected survival change using this method ranged from -2% to +31%, depending on the PATH passage model, and averaged 15% (1.15 times the average historical survival rate; Table A-11).

Table A-11. Estimates of proportional change in SR fall chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

			Survival Estimate	Proportional Change
Base to Current				
a. Juvenile Passage Survival				
Base = average PATH 1980-1992 MY retrospective juvenile survival with D=.24. LGR pool mort not included.				
CRiSP =			0.208	
FLUSH =			0.138	
Current Method 1 = average PATH A2 1980-1992 WY juvenile survival with D=0.24. Accounts for 95-99 may just be good water years.				
CRiSP =			0.205	0.983
FLUSH =			0.182	1.314
average=				**1.148**
Current Method 2 = average SIMPAS 1995-99 juvenile survival with D=0.24				
(LGR pool mort removed from SIMPAS to match PATH)			0.193	
Compared to CRiSP =				0.928
Compared to FLUSH =				1.400
average=				**1.164**
b. Change in Harvest Rate				
Method 1 - PSC Col. R. Mouth Adult Equivalent Harvest Rate For Combined Fisheries				
Base = 80-96 Run Year average	Exp. Rate = 0.6447	(1-E.R.) =	0.3553	
Current = 70% of 88-93 Run Year Average	Exp. Rate = 0.5017	(1-E.R.) =	0.4983	1.403
Method 2 - PATH Ocean and In-River Harvest Rates to Estimate Age-1 to River Survival (Table A-10)				
Ocean: Base = 80-96 Run Year average survival Age-1 to return to CR mouth			0.167	
Ocean: Current = 70% of 88-93 Run Year Average survival Age-1 to return to CR mouth			0.177	1.056
In-River: Base = 80-96 Run Year average	Exp. Rate = 0.300	(1-E.R.) =	0.700	
In-River: Current = 70% of 88-93 Run Year Average	Exp. Rate = 0.245	(1-E.R.) =	0.755	1.078
PATH Combined In-River and Ocean Harvest Reduction				1.139

Table A-11 (continued). Estimates of proportional change in SR fall chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

		Survival Estimate	Proportional Change
c. Combined Base:Current passage and harvest survival changes			
PATH/PATH Hydro Change *	PSC Harvest Change		1.611
PATH/PATH Hydro Change *	PATH Harvest Change		**1.308**
PATH/SIMPAS Hydro Change *	PSC Harvest Change		**1.633**
PATH/SIMPAS Hydro Change *	PATH Harvest Change		1.326
<u>Current to RPA</u>			
a. Juvenile Passage Survival			
Current = SIMPAS including LGR pool mort and D=0.24		0.117	
RPA = SIMPAS 'Aggressive' including LGR pool mort and D=0.24		0.127	1.090
b. Adult Passage Survival			
Current =		0.710	
RPA =		0.740	1.042
c. Combined Juvenile and adult change from RPA			1.136
<u>Combined Base-to-Current and Current -to-RPA Change:</u>			
PATH/PATH Hydro Change *	PSC Harvest Change		1.830
PATH/PATH Hydro Change *	PATH Harvest Change		**1.487**
PATH/SIMPAS Hydro Change *	PSC Harvest Change		**1.855**
PATH/SIMPAS Hydro Change *	PATH Harvest Change		1.507
<u>Base to Breach</u>			
a. Juvenile Passage Survival			
Assumption #1: No Change in EM Between Base and Breach (Same proportional change, whether EM high or low)			
Base = average PATH 1980- 1992 (BY79-91) retrospective juvenile survival with D=.24. LGR pool mort not included. EM=0.19.			
CRiSP =		0.169	
FLUSH =		0.112	
average =		0.140	
Breach Method A = Low Free-flowing Reach Estimate*SIMPAS 95-99*(1-0.19)		0.193	1.371
Breach Method B = High Free-flowing Reach Estimate*SIMPAS 95-99*(1-0.19)		0.275	1.961
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached			
Breach Method A = Low Free-flowing Reach Estimate*SIMPAS 95-99*(1-[0.5*0.19])		0.215	1.532
Breach Method B = High Free-flowing Reach Estimate*SIMPAS 95-99*(1-[0.5*0.19])		0.308	2.190

Table A-11 (continued). Estimates of proportional change in SR fall chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

			Survival Estimate	Proportional Change
Assumption #3: EM is high in base and all goes away when 4 dams breached				
Breach Method A = Low Free-flowing Reach Estimate*SIMPAS 95-99			0.238	1.693
Breach Method B = High Free-flowing Reach Estimate*SIMPAS 95-99			0.340	2.420
b. Adult Passage Survival (Breach expected identical to RPA)				
Base/Current =			0.710	
RPA/Breach =			0.740	1.042
c. Base to Current/Future Harvest Rate Change (as described above)				
Method 1 - PSC Col. R. Mouth Adult Equivalent Harvest Rate For Combined Fisheries				1.403
Method 2 - PATH Ocean and In-River Harvest Rates and Maturation Rates, PSC Ocean Survivals				1.139
d. Combined adult (including harvest) and juvenile survival				
Assumption #1: No Change in EM Between Base and Breach				
PSC Harv+	Method A	+Adult Pass.		2.005
PSC Harv+	Method B	+Adult Pass.		**2.866**
PATH Harv +	Method A	+Adult Pass.		**1.628**
PATH Harv +	Method B	+Adult Pass.		2.328
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached				
PSC Harv+	Method A	+Adult Pass.		2.240
PSC Harv+	Method B	+Adult Pass.		**3.202**
PATH Harv +	Method A	+Adult Pass.		**1.819**
PATH Harv +	Method B	+Adult Pass.		2.601
Assumption #3: EM is high in base and all goes away when 4 dams breached				
PSC Harv+	Method A	+Adult Pass.		2.475
PSC Harv+	Method B	+Adult Pass.		**3.538**
PATH Harv +	Method A	+Adult Pass.		**2.010**
PATH Harv +	Method B	+Adult Pass.		2.874

The second method defined the historical period using PATH passage models, as described above. NMFS did not supplement the historical PATH estimates with SIMPAS passage survival estimates, as in the second method used for SR spring/summer chinook salmon (Section A.5.1.1) because the first available SIMPAS estimate for fall chinook was the 1995 migration year, and those fish would not return as adults until at least 1997. NMFS defined current operations, corresponding to effects of the proposed action, as the 1995-to-1999 average SIMPAS estimates. The second method resulted in expected survival improvements ranging from -7% to +40%, depending on the PATH passage model, and averaged 16% (1.16 times the average historical survival rate) across all assumptions (Table A-11).

The second approach was similar to that included in the July 27, 2000, Draft Biological Opinion, which also compared estimates of current operations, based on SIMPAS, to PATH estimates of historical juvenile survival. Several agencies and organizations criticized that approach, as described for SR spring/summer chinook salmon in Section A.5.1.1. Reservoir survival in PATH's CRiSP passage model is directly calibrated to NMFS' 1995-to-1998, PIT-tag reach survival estimates (Peters et al. 1999), as is SIMPAS (Appendix D). PATH's FLUSH model is not directly calibrated to this data (Peters et al. 1999). However, Figures 4.3.2-4 and 4.3.3-6 of Peters et al. (1999) suggest that the FLUSH model corresponds to the PIT-tag survival estimates, which are highly variable, about as well as the CRiSP model does.

In addition, both the structure and parameterization of the dam passage components of the SIMPAS model are very similar to those used in PATH (Appendix D). The main difference is that some of the parameter estimates used in SIMPAS reflect new information obtained since the PATH models were completed (Appendix D). NMFS compared total juvenile survival (including D = 0.24) estimates generated by the PATH FLUSH model and by SIMPAS for the 1995-through-1998 migration years (Table A-12). In each case, the estimates varied by no more than 3% and averaged 0.5%. CRiSP estimates developed for PATH ended in 1992, so it was not possible to conduct a similar comparison. However, significant discrepancies between PATH and SIMPAS are unlikely, because of the similar structure and similar fit to PIT-tag reach survival estimates, and because both the PATH-only and PATH/SIMPAS methods in this analysis yield similar results.

Table A-12. Comparison of juvenile passage survival estimates from the FLUSH and SIMPAS SR fall chinook salmon passage models.

Migration Year	FLUSH (No LGR pool mort, D=0.24)	SIMPAS (No LGR pool mort, D=0.24)	FLUSH - SIMPAS Difference
1995	0.184	0.208	-0.023
1996	0.198	0.208	-0.010
1997	0.197	0.166	0.032
1998	0.184	0.201	-0.017
Average difference			-0.005

Harvest Rate Reductions. In addition to the change in juvenile passage survival, harvest rates changed significantly during this period. NMFS used two methods to evaluate the reduction in harvest from the 1980-to-1996 return year average. The first method is similar to that used in the July 27, 2000, Draft Biological Opinion, which relies on PATH estimates of age-specific ocean exploitation rates and inriver exploitation rates (Peters et al. 1999; their Table 4.5-2). However, three changes were made in response to comments. First, the Pacific Salmon Commission (PSC) age-specific, ocean natural survival rates (D. Simmons, NMFS, pers. comm 2000) were used in place of the constant natural survival rate assumed in the July 27, 2000, analysis. Second, NMFS applied PSC maturation rates (Simmons 2000) in preference to the CRI propensity to reproduce estimates in the earlier analysis, because of their greater consistency with the methods used by PATH. The modifications produced minor changes in the analysis. The third change (defining the current and future harvest rates as 70% of the 1988-to-1993 ocean and inriver harvest rates), however, reduced the expected survival improvement from that estimated previously. The modified definition of current and future harvest rates is more consistent with the Basinwide Recovery Strategy and with recent NMFS biological opinions on fall chinook harvest than is the previous definition (average 1993-to-1996 harvest rates).

NMFS used the PATH age-specific ocean harvest rates (h2-h6), PSC age-specific, natural ocean survival rates (s2-s6), and PSC maturation rates (b2-b6) to estimate survival from the end of age 1 until adults returned to the mouth of the Columbia River (Table A-13). These cumulative ocean survival rates were then compared using the base and current/future ocean harvest rates to determine the survival improvement resulting from recent harvest rate reductions. The cumulative ocean survival rate was defined according to the following equations.

(7) Survival to Age-3 Returns = $(s2 * (1-h_2) * s3 * (1-h3) * b3)$

(8) Survival to Age-4 Returns = Age-3 Returns $* (1/b3) * (1-b3) * s4 * (1-h4) * b4$

(9) Survival to Age-5 Returns = Age-4 Returns $* (1/b4) * (1-b4) * s5 * (1-h5) * b5$

(10) Survival to Age-6 Returns = Age-5 Returns $* (1/b5) * (1-b5) * s6 * (1-h6) * b6$

(11) Cumulative Survival From End of Age-1 to Columbia River Returns =
Sum of Equations (7) through (10)

Using this approach, NMFS estimates that the reduction in ocean harvest rates has resulted in a 6% survival improvement (Table A-11). PATH's in-river harvest rate estimates indicate that the reduction in inriver harvest has resulted in a 9% survival improvement and that the combination of ocean and in-river harvest reductions has resulted in a 16% survival improvement (Table A-11).

Table A-13. Estimation of fall chinook total survival rate from end of age-1 until return to Columbia River mouth. Ocean exploitation rates are from PATH (Peters et al. 1999, their Table 4.4-3). Natural survival and maturation rates are estimates used by Pacific Salmon Commission (PSC; D. Simmons, pers. Comm 2000) . Base is average 1980-1996 run years (other years not available) and current is 70% of 1988-93 average.

	Age	Base	Current
PATH exploitation rate	2	0.023	0.021
PATH exploitation rate	3	0.089	0.058
PATH exploitation rate	4	0.181	0.164
PATH exploitation rate	5	0.197	0.149
PATH exploitation rate	6	0.208	0.143
PSC natural ocean survival rate	2	0.500	0.500
PSC natural ocean survival rate	3	0.600	0.600
PSC natural ocean survival rate	4	0.700	0.700
PSC natural ocean survival rate	5	0.800	0.800
PSC natural ocean survival rate	6	0.900	0.900
PSC maturation rate	3	0.230	0.230
PSC maturation rate	4	0.720	0.720
PSC maturation rate	5	0.960	0.960
PSC maturation rate	6	1.000	1.000
% Age-1 Fish Surviving to Columbia River mouth	3	0.061	0.064
% Age-1 Fish Surviving to Columbia River mouth	4	0.085	0.090
% Age-1 Fish Surviving to Columbia River mouth	5	0.020	0.023
% Age-1 Fish Surviving to Columbia River mouth	6	0.001	0.001
Total % Return:		**0.167**	**0.177**

NMFS used a second method to estimate the reduction in harvest to address comments by CRITFC and others that the PATH-derived harvest estimates in the July 27, 2000, draft did not match the estimates used by harvest management entities and by NMFS in its harvest biological opinions. Commenters did not question the validity of the PATH estimates, which are based on coded-wire tag (CWT) cohort survival estimates, but suggested that the estimates be reconciled with the PSC and U.S. *v.* Oregon Technical Advisory Committee harvest rate estimates. NMFS was unable to reconcile the estimates, but concluded that there are advantages and disadvantages of both the PATH approach and the harvest modeling approach used by PSC and the Technical Advisory Committee. Therefore, NMFS includes estimates derived from both approaches in this analysis.

The second method relies on results of a PSC model run (Simmons 2000b) that expresses combined ocean and inriver harvest as losses of age-3 to age-5 adult equivalents to the mouth of the Columbia River. NMFS compared average 1980-to-1996 adult equivalent exploitation rates to 70% of average 1988-to-1993 adult equivalent exploitation rates. The estimated survival change using this second method was 40% (Table A-11).

The four combinations of the two alternative harvest change methods and the two alternative juvenile survival change methods result in estimates of total survival change ranging from 31% to 63% (1.31 to 1.63 times the average historical survival rate; Table A-11).

A.5.2.2 Survival Rate Change Associated With the RPA

Juvenile and Adult Passage Survival. Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival beyond the current level associated with the proposed action. NMFS estimates that adult survival will increase from the recent average (71%) to 74% after implementation of the RPA (Table 9.7-5). This represents a proportional survival increase of 4.2% (Table A-11). NMFS estimates that the hydrosystem component of the RPA will increase juvenile survival to below Bonneville Dam, including differential post-Bonneville survival of transported fish (D=0.24), by approximately 9% (Table 9.7-5; Table A-11). The juvenile survival change is based on a comparison of SIMPAS model results for operations associated with the proposed action and RPA, given 1995 to 1999 water conditions. The product of the proportional survival improvements associated with the current conditions (Section A.5.2.1) and the RPA results in an expected survival improvement of 49% to 86% (1.49 to 1.86 times the average 1980-to-1999 survival rate; Table A-11).

A.5.2.3 Survival Rate Change Associated With Breaching Four Snake River Dams

The approach and rationale for used to evaluate effects of breaching on SR fall chinook salmon were nearly identical to those used for SR spring/summer chinook salmon. The main differences between the two analyses are the fall chinook D assumption (previously described in Section A.5.2.1), the EM estimate for nontransported fall chinook, and the estimate of survival through the free-flowing river section following breaching (Table A-10).

Delayed Mortality of Nontransported Fish. As described in Section 6.2.3.3 of the biological opinion, NMFS did not estimate delayed mortality of nontransported SR fall chinook salmon. NMFS considered a value near 0% to be a reasonable approximation of the low end of the range of EM assumptions. NMFS assumed that the highest reasonable assumption was the highest PATH estimate (Peters et al. 1999). The highest PATH estimate that corresponds to D=0.24 is approximately EM=0.19. PATH did not actually estimate EM that corresponds to this D estimate. The EM estimate was derived from a PATH estimate of the STEP term in the PATH fall chinook model that corresponded to D = 0.20. This is the closest available approximation of D = 0.24. The STEP term corresponds to the absolute value of the natural logarithm of EM estimated by PATH (Peters et al. 1999). For fall chinook, Equation 12 was relevant.

(12) $EM = 1 - \exp(-\text{PATH “STEP”})$

Equation 12 was suggested by C. Peters (pers. comm., June 13, 2000, ESSA Technologies, Ltd.), and he provided the relevant PATH STEP results in a June 13, 2000, spreadsheet “fallsteps.xls.”

Juvenile Passage Survival. Empirical estimates of free-flowing reach survival are more limited and difficult to interpret for juvenile SR fall chinook salmon than for SR spring/summer chinook salmon. The PATH participants used two methods to group and extrapolate recent PIT-tag survival estimates (Peters et al. 1999). The first (referred to as "Breach Method A" in Tables A-10 and A-11) results in a free-flowing survival rate of 0.9978 per km, and the second ("Breach Method B" in Tables A-10 and A-11) results in a rate of 0.9995 per km (Annex 1). NMFS finds that both methods are credible and that there is no basis for concluding that one better represents the best available scientific information than the other. Therefore, NMFS used both methods to establish a range of likely survival estimates. When expanded to the 210-km reach, Method A estimates an average survival of 63% versus 90% for Method B.

Summary. Final estimates of the survival changes expected from breaching were evaluated for 12 alternative assumption sets, representing two alternative harvest rate change estimates (PSC versus PATH), two alternative estimates of juvenile survival through the free-flowing reach (Breach method A versus Breach Method B), and three assumptions regarding the extent to which delayed mortality of nontransported fish is reduced following breaching (no change, 50% reduction, complete elimination - Section A.5.1.3). Results are presented in Table A-11.

A.5.3 Upper Columbia River Spring Chinook

The UCR spring chinook population trends estimated in Section A.4 were derived from 1980-to-1998 adult returns. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem and under the RPA represents a change from the average juvenile passage survival rate influencing 1980-to-1998 adult returns. NMFS includes an estimate of expected survival changes through projects above McNary Dam, consistent with implementation of the proposed Mid-Columbia HCP, as anticipated in the Basinwide Recovery Strategy. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average 1980-to-1998 adult survival rate. NMFS estimates that the adult survival rate associated with the RPA and with breaching will, however, be an improvement from the 1980-to-1998 adult survival rate. The following sections present the methods and estimates for these juvenile and adult passage survival rate changes. Harvest rate changes have been, and are expected to continue to be, relatively minor for this ESU, so are not included in this analysis. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-14 provides an overview of the assumptions and life stages addressed in this analysis, which are discussed in more detail in the following sections.

A.5.3.1 Survival Rate Change Associated With the Proposed Action

Juvenile FCRPS (McNary Dam to Bonneville Dam) Passage Survival. NMFS estimates that the juvenile UCR spring chinook salmon survival rate associated with the proposed action is reduced from the average survival rate influencing 1980-to-1996 adult returns. This is because transportation from McNary Dam has been discontinued and because structural and operational modifications to the four lower Columbia River dams have been implemented since 1980

Table A-14. Key assumptions affecting the range of Upper Columbia River spring chinook salmon survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct MCN-BON FCRPS Juvenile Passage Survival	**Base:** Single estimate from QAR analysis **Current:** Single estimate from SIMPAS model	**Base:** Single estimate from QAR analysis **RPA:** Single estimate from SIMPAS model	N/A
Survival Above MCN	Assume HCP implementation per All-H Paper. Single estimate of base-to-HCP change, from QAR analysis.	Assume HCP implementation per All-H Paper. Single estimate of base-to-HCP change, from QAR analysis.	N/A
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D)	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **Current:** no transportation	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **RPA:** no transportation	N/A
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value	Assumed constant for base and RPA, so does not affect estimate, regardless of value	N/A
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	N/A
Harvest	Similar in base and current/future, so no change included in calculations.	Similar in base and current/future, so no change included in calculations.	N/A
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	N/A

(Section 6.3.1.3 of the biological opinion). The project modifications have improved survival for inriver migrants, but the system survival from McNary Dam to Bonneville Dam has declined from the average rate during the base period (Cooney 2000), when a significant proportion of the smolts were transported. The proposed action specifies that nearly all fish will remain in the river because of very low returns of transported smolts in 1994, after the new McNary bypass system was constructed (Appendix B to 1998 FCRPS Biological Opinion).

The size of the estimated decline in McNary-to-Bonneville-Dam juvenile survival depends on the estimate of historical differential post-Bonneville survival (D) during the years when smolts were transported from McNary Dam. NMFS evaluated D estimates ranging from 0.8 to 1.0, based on results of historical McNary transportation studies (Cooney 2000; reviewed in NMFS 2000). Only a fraction of the run is transported for the proposed action, so estimating D under the proposed action is not necessary for this ESU. Cooney (2000, his Table 23) estimated 1980-to-

1994 juvenile survival from McNary to Bonneville at 60.7% and 69.0% for historical D estimates of 0.8 and 1.0, respectively.

NMFS estimated juvenile survival associated with the proposed action (current survival) using the SIMPAS passage model. SIMPAS estimated McNary-to-Bonneville Dam survival estimates from 1994 to 1999. These averaged 57.5%. The resulting change in lower river survival associated with the proposed action was -5% to -17% (Table A-15).

Juvenile Non-Federal Project Survival. The Basinwide Recovery Strategy identifies implementation of the Mid-Columbia HCP at five public utility district (PUD) projects as a probable element of recovery planning that is, therefore, included in the analysis. The Basinwide Recovery Strategy estimates that this action will be implemented within 2 to 5 years. Cooney (2000, his Table 20) estimates that implementing the HCP will improve survival 28% for the Wenatchee population, 40% for the Entiat population, and 49% for the Methow population (Table A-15).

Summary. Combining changes in survival resulting from implementation of the Mid-Columbia HCP and modifying the four lower Columbia River FCRPS projects result in a 7% to 41% increase in survival, depending on the population under consideration and the historical D estimate (Table A-15).

A.5.3.2 Survival Rate Change Associated With the RPA

Juvenile and Adult Passage Survival. Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival through the four lower Columbia River projects beyond the current level associated with the proposed action. NMFS estimates that adult survival will increase from the recent average (90.8%) to 92.2% after implementation of the RPA (Table 9.7-5). This represents a proportional survival increase of 1.5% (Table A-15). NMFS estimates that the hydrosystem component of the RPA will increase recent average juvenile survival from McNary Dam to Bonneville Dam (57.5%) by approximately 15.5%, to a new survival rate of 66.4% (Table 9.7-5; Table A-15). The juvenile survival change is based on a comparison of SIMPAS model results for operations associated with the proposed action and RPA, given 1994 to 1999 water conditions. The product of the proportional survival improvements associated with the current conditions (Section A.5.3.1) and the RPA results in an expected survival improvement of 25% to 65% (1.25 to 1.65 times the average 1980-to-1999 survival rate), depending upon the population under consideration and the historical D estimate (Table A-15).

A.5.3.3 Survival Rate Change Associated With Breaching

No quantifiable survival improvements are expected for this ESU after four Snake River dams are breached.

Table A-15. Estimates of proportional change in UCR spring chinook survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
Base to Current		
a. Survival Above McNary (All Life Stages)		
Base to HCP from Cooney (2000; his Table 20)		
Wenatchee		1.280
Entiat		1.400
Methow/Okanogan		1.490
b. Juvenile Survival McNary-Bonneville		
Base #1 = 1980-94 Survival With D=0.8 (Cooney 2000; his Table 23)	0.607	
Base #2 = 1980-94 Survival With D=1.0 (Cooney 2000; his Table 23)	0.690	
Current = SIMPAS MCN-BON (No Transport) 1994-1999	0.575	0.947
		0.833
c. Combined Base:Current above- and below-McNary survival changes		
Wenatchee		
Hist. D=0.8		**1.212**
Hist. D=1.0		**1.067**
Entiat		
Hist. D=0.8		**1.326**
Hist. D=1.0		**1.167**
Methow/Okanogan		
Hist. D=0.8		**1.411**
Hist. D=1.0		**1.242**
Current to RPA		
a. Juvenile Passage Survival		
Current = SIMPAS MCN-BON (No Transport) 1994-1999	0.575	
RPA = SIMPAS MCN-BON (No Transport) 1994-1999	0.664	1.155
b. Adult Passage Survival		
Current =	0.908	
RPA =	0.922	1.015
c. Combined Juvenile and adult change from RPA		1.172
Combined Base-to-Current and Current-to-RPA Change:		
Wenatchee		
Hist. D=0.8		**1.421**
Hist. D=1.0		**1.250**
Entiat		
Hist. D=0.8		**1.554**
Hist. D=1.0		**1.367**
Methow/Okanogan		
Hist. D=0.8		**1.654**
Hist. D=1.0		**1.455**

A.5.4 Upper Willamette River Chinook

NMFS is unable to quantify any survival changes for this ESU as a result of any of the actions evaluated in the analysis.

A.5.5 Lower Columbia River Chinook

The current population trends and needed survival changes summarized for this ESU in Tables A-2 through A-6 refer only to spawning aggregations below Bonneville Dam. Operation of the FCRPS under the actions considered in this analysis may influence survival or spawning success of these aggregations, but NMFS is unable to quantify those effects.

A.5.6 Snake River Steelhead

The SR steelhead A-Run and B-Run aggregate trends estimated in Section A.4 were derived from 1980-to-1997 adult returns. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem and under the RPA represents an improvement from the average juvenile passage survival rate influencing 1980-to-1997 adult returns. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average 1980-to-1997 adult survival rate. However, NMFS estimates that the adult survival rate associated with the RPA and with breaching will be an improvement from the 1980-to-1996 adult survival rate. Current and expected future harvest rates are lower than the average harvest rates affecting 1980-to-1997 returning adults, which also results in increased survival. The following sections review the methods and estimates for these juvenile and adult survival rate changes. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-16 provides an overview of the assumptions and life stages addressed in this analysis, which are discussed in more detail in the following sections.

A.5.6.1 Survival Rate Change Associated With the Proposed Action

Proportional Change in Juvenile Passage Survival. No estimates of average juvenile SR steelhead survival during the base period are available. Neither PATH nor NMFS estimated the SR steelhead survival rates, including transported fish and possible indirect effects. Because direct estimates of historical steelhead juvenile passage survival are not available, NMFS assumes that the proportional change in juvenile SR steelhead survival from the base to current (proposed action) condition equals the proportional change estimated for SR spring/summer chinook salmon (24% to 32%, depending on method; Section A.5.1.1; Tables A-17 and A-18). Improvements to the system over that period (e.g., new bypasses, increased spill levels, increased flow rates, and new transportation facilities) probably have affected spring-migrating yearling steelhead and yearling chinook similarly. The 1998 FCRPS Biological Opinion contains details regarding similar effects of the hydrosystem on the two ESUs. The 1998 FCRPS Biological Opinion relied on a comparison of SR spring/summer chinook and SR steelhead to draw conclusions for steelhead. Additional information about effects of the hydrosystem on each ESU is available in NMFS (2000e,h,i).

Table A-16. Key assumptions affecting the range of Snake River steelhead survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct LGR-BON Juvenile Passage Survival	Assumed identical to base-to-current survival change estimated for SR spring/summer chinook: Method 1: PATH/PATH SR spring/summer incremental change Method 2: PATH/SIMPAS spring/summer incremental change	Method 1: PATH/PATH SR spring/summer base-to-current incremental change, coupled with SIMPAS SR steelhead current-to-RPA survival change Method 2: PATH/SIMPAS SR spring/summer base-to-current incremental change, coupled with SIMPAS SR steelhead current-to-RPA survival change	**Base**: Method 1 and Method 2, as described for other actions **Breach**: One estimate, derived from LGR-MCN free-flowing reach survival and MCN-BON from SIMPAS RPA estimate
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D)	Average D=0.53 and D=0.58 for both base and proposed action, so does not affect estimate	Average D=0.52 and D=0.58 for both base and proposed action, so does not affect estimate	**Base:** Average D=0.52 and D=0.58 **Breach**: No transportation, so D not relevant. All fish have equivalent post-BON survival, which is functionally equivalent to D=1.0.
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value(assume range identical to SR spring/summer chinook)	Assumed constant for base and RPA, so does not affect estimate, regardless of value (assume range identical to SR spring/summer chinook)	**Approach 1**: Assumed constant for base and breach, so does not affect estimate, regardless of value **Approach 2:** High in base period (71% to 74% - from SR spring/summer chinook); half that after breaching 4 of 8 dams (36% to 37%) **Approach 3:** High in base period (71% to 74% - from SR spring/summer chinook); 0% after breaching 4 dams
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	Same survival improvement as base to RPA. Delayed mortality, if any, identical in base and breach, so does not affect estimate.
Harvest	One method, based on US *v* Oregon TAC estimates	Identical to approach described for proposed action.	Identical to approach described for proposed action.
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion

Table A-17. Estimates of proportional change in SR A-Run steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

			Survival Estimate	Proportional Change
Base to Current				
a. Juvenile Passage Survival				
Assume change is equal to proportional change for SR sp/sum				
Method 1 Base:Current Survival Change From Table A-7				1.323
Method 2 Base:Current Survival Change From Table A-7				1.239
b. Change in Harvest Rate				
Base: TAC 1984-98 (84 is first year avail - can't use 80)	0.161	(1-harvest)=	0.839	
Current/Future Harvest (Recent A:B ratio * B cap of 17%)	0.101	(1-harvest)=	0.899	1.072
c. Combined Base:Current passage and harvest survival changes				
SR sp/sum Method 1 Juvenile Change * Harvest Change				**1.418**
SR sp/sum Method 2 Juvenile Change * Harvest Change				**1.327**
Current to RPA				
a. Juvenile Passage Survival				
Current = SIMPAS including D=0.52-0.58			0.486	
RPA = SIMPAS RPA including D=0.52-58			0.507	1.044
b. Adult Passage Survival				
Current =			0.773	
RPA =			0.803	1.039
c. Combined Juvenile and adult change from RPA				1.085
Combined Base-to-Current and Current -to-RPA Change:				
PATH/PATH + TAC Harvest Base:current				**1.540**
PATH/SIMPAS Hydro + TAC Harvest Base:Current				**1.441**
Current to Breach				
a. Juvenile Passage Survival				
Assumption #1: No Change in EM Between Base and Breach (Same proportional change, whether EM high or low)				
Current = SIMPAS including D=0.52-0.58*(1-avg[.709,.743])			0.139	
Breach = Natural For Snake*MCN-BON SIMPAS RPA*(1-avg(.709,.743))			0.173	1.245
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached				
Breach = Natural For Snake*MCN-BON SIMPAS RPA*(1-[0.5*avg(.709,.743)])			0.401	2.894
Assumption #3: EM is high in base and all goes away when 4 dams breached				
Breach = Natural For Snake*MCN-BON SIMPAS RPA			0.630	4.543

Table A-17 (continued). Estimates of proportional change in SR A-Run steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
b. Adult Passage Survival (Breach expected identical to RPA)		
c. Juvenile RPA-to-Breach Changes * Current-to-RPA, as described above		
Assumption #1: No Change in EM Between Base and Breach		
Method 1 base:current		**1.766**
Method 2 base:current		**1.653**
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached		
Method 1 base:current		**4.105**
Method 2 base:current		**3.842**
Assumption #3: EM is high in base and all goes away when 4 dams breached		
Method 1 base:current		**6.444**
Method 2 base:current		**6.031**

Table A-18. Estimates of proportional change in SR B-Run steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

			Survival Estimate	Proportional Change
Base to Current				
a. Juvenile Passage Survival				
Assume change is equal to proportional change for SR sp/sum				
Method 1 Base:Current Survival Change From Table A-7				1.323
Method 2 Base:Current Survival Change From Table A-7				1.239
b. Change in Harvest Rate				
Base: TAC 1984-98 (84 is first year avail - can't use 80)	0.286	(1-harvest)=	0.714	
Current/Future Harvest (17%, from All-H Paper and recent biops)	0.170	(1-harvest)=	0.830	1.163
c. Combined Base:Current passage and harvest survival changes				
SR sp/sum Method 1 Juvenile Change * Harvest Change				**1.539**
SR sp/sum Method 2 Juvenile Change * Harvest Change				**1.441**
Current to RPA				
a. Juvenile Passage Survival				
Current = SIMPAS including D=0.52-0.58			0.486	
RPA = SIMPAS RPA including D=0.52-58			0.507	1.044
b. Adult Passage Survival				
Current =			0.773	
RPA =			0.803	1.039
c. Combined Juvenile and adult change from RPA				1.085
Combined Base-to-Current and Current -to-RPA Change:				
PATH/PATH + TAC Harvest Base:current				**1.671**
PATH/SIMPAS Hydro + TAC Harvest Base:Current				**1.564**
Current to Breach				
a. Juvenile Passage Survival				
Assumption #1: No Change in EM Between Base and Breach (Same proportional change, whether EM high or low)				
Current = SIMPAS including D=0.52-0.58*(1-avg[.709,.743])			0.139	
Breach = Natural For Snake*MCN-BON SIMPAS RPA*(1-avg(.709,.743))			0.173	1.245
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached				
Breach = Natural For Snake*MCN-BON SIMPAS RPA*(1-[0.5*avg(.709,.743)])			0.401	2.894
Assumption #3: EM is high in base and all goes away when 4 dams breached				
Breach = Natural For Snake*MCN-BON SIMPAS RPA			0.630	4.543

Table A-18 (continued). Estimates of proportional change in SR B-Run steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
b. Adult Passage Survival (Breach expected identical to RPA)		
c. Juvenile RPA-to-Breach Changes * Current-to-RPA, as described above		
Assumption #1: No Change in EM Between Base and Breach		
Method 1 base:current		**1.916**
Method 2 base:current		**1.793**
Assumption #2: EM is high in base and 1/2 goes away when 4 dams breached		
Method 1 base:current		**4.455**
Method 2 base:current		**4.169**
Assumption #3: EM is high in base and all goes away when 4 dams breached		
Method 1 base:current		**6.993**
Method 2 base:current		**6.545**

Harvest Reductions. In addition to the change in juvenile passage survival, harvest rates changed significantly during this period. The average 1984-through-1997 harvest rates for A-run and B-run steelhead were obtained from the U.S. *v.* Oregon Technical Advisory Committee (ODFW and WDFW 2000; Table A-19). Estimates for 1980-through-1983 returns were not available, except for the run at large. NMFS compared this historical average with the Basinwide Recovery Strategy's 17% B-run harvest cap, which represents the most likely current and future B-run harvest rate. The Basinwide Recovery Strategy does not describe a similar harvest rate for A-run steelhead, so an approximation was obtained by multiplying the B-run harvest cap by the recent ratio of A:B harvest rates (Table A-19). The result was a 10% A-run current and future harvest rate. The reduced harvest rate represents a 7.2% A-run survival increase from the average survival during the 1980-to-1997 period and a 16.3% B-run survival increase.

Summary. The reduced harvest rates and the two alternative methods for estimating the juvenile survival improvement result in estimates of total survival change ranging from 33% to 42% (1.33 to 1.42 times the average historical survival rate) for A-run steelhead and 44% to 54% (1.44 to 1.54 times the average historical survival rate) for B-run steelhead (Tables A-17 and A-18).

A.5.6.2 Survival Rate Change Associated With the RPA

General Approach. Because juvenile survival during the base period is unknown, NMFS was unable to directly estimate the change in survival from the base period to the RPA. Instead, NMFS estimated the change in survival from the proposed action (current conditions) to the RPA, then multiplied that proportional change by the previously estimated proportional change from base-to-current survival (Tables A-17 and A-18).

Table A-19. SR steelhead harvest rates from ODFW and WDFW (2000, their Table 16). A's and B's separated by length (<78 cm and >78 cm).

Run Year	Wild "A" Harvest Rate w/o Nontreaty Fall impacts	Wild "A" Harvest Rate with annual 2% Nontreaty Fall impacts (Dygert 11/30 pers. Comm.)	Wild "B" Harvest Rate w/o Nontreaty Fall impacts	Wild "B" Harvest Rate with annual 2% Nontreaty Fall impacts (Dygert 11/30 pers. Comm.)	Ratio A:B Harvest Rates
1984	0.120	0.140	0.366	0.386	0.363
1985	0.207	0.227	0.310	0.330	0.688
1986	0.138	0.158	0.267	0.287	0.551
1987	0.157	0.177	0.372	0.392	0.452
1988	0.171	0.191	0.234	0.254	0.752
1989	0.159	0.179	0.350	0.370	0.484
1990	0.160	0.180	0.215	0.235	0.766
1991	0.146	0.166	0.300	0.320	0.519
1992	0.162	0.182	0.263	0.283	0.643
1993	0.152	0.172	0.191	0.211	0.815
1994	0.103	0.123	0.186	0.206	0.597
1995	0.104	0.124	0.186	0.206	0.602
1996	0.089	0.109	0.346	0.366	0.298
1997	0.104	0.124	0.143	0.163	0.761
1998	0.088	0.108	0.156	0.176	0.614
1999	0.076	0.096	0.127	0.147	0.653
2000					
84-97 Mean		**0.161**		**0.286**	
Future B Harvest Rate (All-H Paper)				**0.170**	
Recent Ratio A:B (93-98)					**0.592**
Future A Harvest Rate (= recent ratio * Future B)		**0.101**			

Juvenile and Adult Passage Survival. Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival beyond the current level associated with the proposed action. NMFS estimates that adult survival will increase from the recent average (77.3%) to 80.3% after implementation of the RPA (Table 9.7-5). This represents a proportional survival increase of 3.9% (Tables A-17 and A-18). NMFS estimates that the hydrosystem component of the RPA will increase juvenile survival to below Bonneville Dam, including differential post-Bonneville survival of transported fish (D=0.52 to 0.58), by approximately 4.4% (Table 9.7-5; Tables A-17 and A-18). The juvenile survival change is based on a comparison of SIMPAS model results for operations associated with the proposed action (survival averages 48.6%) and the RPA (survival averages 50.7%), given 1994-to-1999 water conditions.

Summary. The product of the proportional survival improvements associated with the current conditions (Section A.5.1.1) and the RPA results in an expected survival improvement of 44% to 54% (1.44 to 1.54 times the average 1980-to-1999 survival rate; Table A-17) for A-run steelhead and 56% to 67% (1.56 to 1.67 times the average 1980-to-1999 survival rate; Table A-18) for B-run steelhead. The range of estimates reflects the two alternative methods used to estimate the SR spring/summer chinook, base-to-current survival change.

A.5.6.3 Survival Rate Change Associated With Breaching

Juvenile Direct Survival and Delayed Mortality. The approach and rationale for used to evaluate effects of breaching on SR steelhead were nearly identical to those used for SR spring/summer chinook salmon (Table A-16). The main difference was that the same two-step approach used for the RPA was applied. NMFS first estimated the base-to-current survival change, including the two SR spring/summer chinook estimates. Then NMFS estimated the current-to-breach survival change. Direct free-flowing and McNary-to-Bonneville reach survival estimates were specific to SR steelhead, as were D estimates. However, the changes in extra mortality evaluated for breaching relied upon SR spring/summer chinook estimates of EM. As described in Section 6.2.3.3 of the biological opinion, NMFS did not estimate delayed mortality of nontransported SR steelhead. NMFS concluded that it is reasonable to apply the same range of assumptions to SR steelhead as NMFS applied to SR spring/summer chinook. NMFS considered a value near 0% to be a reasonable approximation of the low end of the range of EM assumptions. NMFS assumed that the highest reasonable assumption was the highest PATH estimate for SR spring/summer chinook salmon (71% to 74%; Marmorek et al. 1998). Details of estimates are displayed in Tables A-18 and A-19.

Summary. Final estimates of the survival changes expected from breaching were evaluated for six alternative assumption sets, representing two alternative estimates of base-to-current juvenile survival changes and three assumptions regarding the extent to which EM is reduced following breaching (no change, 50% reduction, complete elimination - Section A.5.1.3). Results are presented in Tables A-18 and A-19.

A.5.7 Upper Columbia River Steelhead

The UCR steelhead trends estimated in Section A.4 were derived from 1980-to-1999 adult returns for the individual populations addressed by the QAR analysis and from 1980-to-1996 adult returns for the aggregate CRI analysis. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem and under the RPA represents a change from the average juvenile passage survival rate influencing 1980-to-1996 or -1999 (base period) adult returns. NMFS includes an estimate of expected survival changes through projects above McNary Dam, consistent with implementation of the proposed Mid-Columbia HCP, as anticipated in the Basinwide Recovery Strategy. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average base period adult survival rate. However, NMFS estimates that the adult survival rate associated with the RPA and with breaching will be an improvement from the base period adult survival rate.

Current and expected future harvest rates are lower than the average harvest rates affecting 1980-to-1997 returning adults, which also results in increased survival. The following sections review the methods and estimates for these juvenile and adult passage survival rate changes. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-20 provides an overview of the assumptions and life stages addressed in this analysis. These assumptions and life stages are discussed in more detail in the following sections.

Table A-20. Key assumptions affecting the range of Upper Columbia River steelhead survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct MCN-BON FCRPS Juvenile Passage Survival	**Base:** Single estimate from QAR analysis **Current:** Single estimate from SIMPAS model	**Base:** Single estimate from QAR analysis **RPA:** Single estimate from SIMPAS model	N/A
Survival Above MCN	Assume HCP implementation per All-H Paper. Single estimate of base-to-HCP change, from QAR analysis.	Assume HCP implementation per All-H Paper. Single estimate of base-to-HCP change, from QAR analysis.	N/A
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D)	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **Current:** no transportation	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **RPA:** no transportation	N/A
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value	Assumed constant for base and RPA, so does not affect estimate, regardless of value	N/A
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	N/A
Harvest	One method, based on US *v* Oregon TAC estimates	Identical to approach described for proposed action.	N/A
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	N/A

A.5.7.1 Survival Rate Change Associated With the Proposed Action

Juvenile FCRPS (McNary Dam to Bonneville Dam) Passage Survival. NMFS estimates that the juvenile UCR steelhead survival rate associated with the proposed action is reduced from the average survival rate influencing 1980-to-1996 adult returns. This is because transportation from McNary Dam has been discontinued, and because structural and operational modifications to the four lower Columbia River dams have been implemented since 1980 (Section 6.3.1.3 of the biological opinion). The project modifications have improved survival for inriver migrants, but the system survival from McNary Dam to Bonneville has declined from the average rate during the base period (Cooney 2000), when a significant proportion of the smolts were transported. The proposed action specifies that nearly all fish will remain in the river because of very low returns of transported smolts in 1994, after the new McNary bypass system was constructed (Appendix B to the 1998 FCRPS Biological Opinion).

NMFS used the base period survival estimate from Cooney (2000, his Table 23), which is identical to the base period estimate for UCR spring chinook (Section A.5.3.1). This estimate varies, based on assumptions regarding historical differential post-Bonneville survival (D) during the years when smolts were transported from McNary Dam. NMFS evaluated D estimates ranging from 0.8 to 1.0, based on results of historical McNary transportation studies (Cooney 2000; reviewed in NMFS 2000). Only a fraction of the run is transported for the proposed action, so estimating D under the proposed action is not necessary for this ESU. Cooney (2000, his Table 23) estimated 1980-to-1994 juvenile survival from McNary to Bonneville at 60.7% and 69.0% for historical D estimates of 0.8 and 1.0, respectively.

NMFS estimated juvenile survival associated with the proposed action (current survival) using the SIMPAS passage model. SIMPAS estimated McNary-to-Bonneville survival estimates from 1994 to 1999. These averaged 58.8%. The resulting change in lower river survival associated with the proposed action was -3% to -15% (Table A-21).

Juvenile Non-Federal Project Survival. The Basinwide Recovery Strategy identifies implementation of the Mid-Columbia HCP at five PUD projects as a probable element of recovery planning that is, therefore, included in the analysis. The Basinwide Recovery Strategy estimates that this action will be implemented within 2 to 5 years. Cooney (2000, his Table 20) estimates that implementing the HCP will improve survival 23% for the Wenatchee population, 33% for the Entiat population, and 38% for the Methow population (Table A-21).

Harvest Reductions. In addition to the change in juvenile passage survival, harvest rates also declined during this period. UCR steelhead are subjected to similar harvest rates as SR A-Run steelhead. Therefore, NMFS applied the change in harvest rate estimated for SR A-run steelhead (Tables A-17 and A-19) to this ESU. This reduced harvest rate results in a 7.2% survival improvement.

Summary. Combining changes in survival resulting from implementation of the Mid-Columbia HCP, reduced harvest rates, and modifications to the four lower Columbia River FCRPS projects results in a 12% to 43% increase in survival, depending on the population under consideration and the historical D estimate (Table A-21).

Table A-21. Estimates of proportional change in UCR steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

					Survival Estimate	Proportional Change
Base to Current						
a. Survival Above McNary (All Life Stages)						
Base to HCP from Cooney (2000; his Table 20)						
	Wenatchee					1.230
	Entiat					1.330
	Methow/Okanogan					1.380
b. Juvenile Survival McNary-Bonneville						
Base #1 = 1980-94 Survival With D=0.8 (Cooney 2000; his Table 23)					0.607	
Base #2 = 1980-94 Survival With D=1.0 (Cooney 2000; his Table 23)					0.690	
Current = SIMPAS MCN-BON (No Transport) 1994-1999					0.588	0.969
						0.852
c. Harvest Rate - same as SR A-Run Steelhead (Tables A-12, A-14)						
Base: TAC 1984-98 (84 is first year avail - can't use 80)			0.161	(1-harvest)=	0.839	
Current/Future Harvest (Recent A:B ratio * B cap of 17%)			0.101	(1-harvest)=	0.899	1.072
d. Combined Base:Current above- and below-McNary survival changes						
	Wenatchee	Hist. D=0.8				**1.277**
		Hist. D=1.0				**1.123**
	Entiat	Hist. D=0.8				1.381
		Hist. D=1.0				1.215
	Methow/Okanogan	Hist. D=0.8				**1.433**
		Hist. D=1.0				**1.260**
Current to RPA						
a. Juvenile Passage Survival						
Current = SIMPAS MCN-BON (No Transport) 1994-1999					0.588	
RPA = SIMPAS MCN-BON (No Transport) 1994-1999					0.699	1.152
b. Adult Passage Survival						
Current =					0.879	
RPA =					0.893	1.016
c. Combined Juvenile and adult change from RPA						1.170
Combined Base-to-Current and Current-to-RPA Change:						
	Wenatchee	Hist. D=0.8				**1.494**
		Hist. D=1.0				**1.314**
	Entiat	Hist. D=0.8				1.616
		Hist. D=1.0				1.421
	Methow/Okanogan	Hist. D=0.8				**1.676**
		Hist. D=1.0				**1.475**

A.5.7.2 Survival Rate Change Associated With the RPA

Juvenile and Adult Passage Survival. Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival through the four lower Columbia River projects beyond the current level associated with the proposed action. NMFS estimates that adult survival will increase from the recent average (87.9%) to 89.3% after implementation of the RPA (Table 9.7-5). This represents a proportional survival increase of 1.6% (Table A-21). NMFS estimates that the hydrosystem component of the RPA will increase recent average juvenile survival from McNary Dam to Bonneville Dam (58.8%) by approximately 15.2%, to a new survival rate of 67.7% (Table 9.7-5; Table A-21). The juvenile survival change is based on a comparison of SIMPAS model results for operations associated with the proposed action and RPA, given 1994-to-1999 water conditions. The product of the proportional survival improvements associated with the current conditions (Section A.5.7.1) and the RPA results in an expected survival improvement of 31% to 68% (1.31 to 1.68 times the average base period survival rate), depending upon the population under consideration and the historical D estimate (Table A-21).

A.5.7.3 Survival Rate Change Associated With Breaching

No quantifiable survival improvements are expected for this ESU after four Snake River dams are breached.

A.5.8 Middle Columbia River Steelhead

The MCR steelhead trends estimated in Section A.4 were derived from 1980-to-1994 (Yakima and Warm Springs) or 1980-to-1996 (Deschutes and Umatilla) adult returns. NMFS estimates that the average juvenile FCRPS passage survival rate under current operations and configuration of the hydrosystem and under the RPA represents an improvement from the average juvenile passage survival rate influencing base period adult returns. NMFS concludes that the current adult passage survival rate through the FCRPS has not changed from the average base period adult survival rate. However, NMFS estimates that the adult survival rate associated with the RPA will be an improvement from the base period adult survival rate. Current and expected future harvest rates are lower than the average harvest rates affecting base period returning adults, which also results in increased survival. The following sections review the methods and estimates for these juvenile and adult survival rate changes. NMFS was unable to quantify survival rate changes for other life stages or actions. Table A-22 provides an overview of the assumptions and life stages addressed in this analysis. These assumptions and life stages are discussed in more detail in the following sections.

Table A-22. Key assumptions affecting the range of Middle Columbia River steelhead survival change (from base period) estimates expected from three actions.

	Proposed Action	RPA	Breach
Direct Juvenile Passage Survival	**Base:** Single estimate for each stock from QAR analysis **Current:** Single estimate for each stock from SIMPAS model	**Base:** Single estimate for each stock from QAR analysis **RPA:** Single estimate for each stock from SIMPAS model	N/A
Differential Post-BON Survival of Transported, Compared to Non-Transported, Fish (D) - *Only Applies to Yakima Stock*	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **Current:** no transportation	**Base D=0.8:** QAR low assumption for years in which transportation occurred **Base D=1.0:** QAR high assumption for years in which transportation occurred **RPA:** no transportation	N/A
Delayed Mortality of Non-Transported Fish (EM)	Assumed constant for base and proposed action, so does not affect estimate, regardless of value	Assumed constant for base and RPA, so does not affect estimate, regardless of value	N/A
Adult Survival	Constant for base and proposed action, so does not affect estimate. Delayed mortality, if any, identical in base and proposed action, so does not affect estimate.	Improves from base to RPA, as described in Table 9.7-5 of Biological Opinion. Delayed mortality, if any, identical in base and RPA, so does not affect estimate.	N/A
Harvest	One method, based on US *v* Oregon TAC estimates	Identical to approach described for proposed action.	N/A
Other Life Stages and Actions	Not included in quantitative analysis; qualitative discussion in Biological Opinion	Not included in quantitative analysis; qualitative discussion in Biological Opinion	N/A

A.5.8.1 Survival Rate Change Associated With the Proposed Action

Juvenile Passage Survival. The MCR steelhead spawning aggregations evaluated in this analysis pass from two to four FCRPS dams during their juvenile migrations. For each spawning aggregation, an estimate of the base period survival rate is available from the QAR analysis (Cooney 2000), and an estimate of survival under the proposed action (current survival) is available from SIMPAS modeling. The following discussion provides details for each stock.

The Yakima River spawning aggregation passes through the same four FCRPS projects (McNary Dam to Bonneville Dam) as the UCR steelhead ESU and is, therefore, likely to experience the same survival change estimated for that ESU (Tables A-21 and A-23). The FCRPS project modifications have improved survival for inriver migrants, but the system survival from McNary Dam to Bonneville Dam has declined from the average rate during the base period, when a significant proportion of the smolts were transported (Cooney 2000; Table A-23). The proposed action specifies that nearly all fish will remain in the river because of very low returns of transported smolts in 1994, after the new McNary bypass system was constructed (Appendix B to 1998 FCRPS Biological Opinion). The size of the estimated decline in McNary-Bonneville juvenile survival for the Yakima aggregation depends on the estimate of historical differential post-Bonneville survival (D; see Section 6.2.3.3) during the years when smolts were transported from McNary Dam. NMFS evaluated D estimates ranging from 0.8 to 1.0, based on results of historical McNary transportation studies (Cooney 2000; reviewed in NMFS 2000). Only a fraction of the run is transported for the proposed action, so estimating D under the proposed action is not necessary for this ESU. Cooney (2000, his Table 23) estimated 1980-to-1994 juvenile survival from McNary to Bonneville at 60.7% and 69.0% for historical D estimates of 0.8 and 1.0, respectively.

NMFS estimated Yakima River stock juvenile survival associated with the proposed action (current survival) using the SIMPAS passage model. SIMPAS estimated McNary-to-Bonneville survival estimates from 1994 to 1999. These averaged 58.8%. The resulting change in lower river survival associated with the proposed action was -3% to -15% (Table A-23).

The Umatilla River spawning aggregation passes through three FCRPS projects (John Day Dam to Bonneville Dam). These projects are all below the last transportation site, so no juveniles were transported in either the base or the current period. NMFS compared the estimate in Cooney (2000, his Table 22) of average 1980-to-1994 inriver survival through these projects (61.3%) with the average SIMPAS 1994-to-1999 estimate through the same projects (65.1%). The resulting survival change for the Umatilla spawning aggregate is 6% (Table A-23).

The Deschutes River and Warm Springs spawning aggregations pass through two FCRPS projects (The Dalles Dam and Bonneville Dam). These projects are also below the last transportation site, so no fish were transported in either the base or the current period. NMFS compared the estimate in Cooney (2000, his Table 22) of average 1980-to-1994 inriver survival through these projects (75.7%) with the average SIMPAS 1994-to-1999 estimate through the same projects (75.8%). Based on these estimates, no change in juvenile survival is anticipated for the Deschutes and Warm Springs spawning aggregations (Table A-23).

Harvest Rate Reductions. In addition to the change in juvenile passage survival, harvest rates also declined during this period. MCR steelhead are subjected to similar harvest rates as SR A-Run steelhead. Therefore, NMFS applied the change in harvest rate estimated for SR A-run steelhead (Tables A-17 and A-19) to this ESU. This reduced harvest rate results in a 7.2% survival improvement (Table A-23).

Summary. Combining changes in survival resulting from reduced harvest rates and modifications to the four lower Columbia River FCRPS projects results in a -9% to +14% change in survival, depending on the spawning aggregation under consideration and the historical D estimate (Table A-23).

Table A-23. Estimates of proportional change in MCR steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

				Survival Estimate	Proportional Change
Base to Current					
a. Juvenile Survival					
Yakima = assume same MCN-BON proportional change as for UCR steelhead					
	Base 80-94 with D=0.8			0.607	
	Base 80-94 with D=1.0			0.690	
	Current SIMPAS MCN-BON			0.588	0.969
					0.852
Umatilla = assume QAR est. (.81*.87*.87) base					
	Base 80-94			0.613	
	Current SIMPAS JDA-BON			0.651	1.062
Warm Spring and deschutes= assume QAR (.87*.87)					
	Base 80-94			0.757	
	Current SIMPAS TDA-BON			0.758	1.001
b. Harvest Change - same as SR A-Run Steelhead					
Base: TAC 1984-98 (84 is first year avail - can't use 80)		0.161	(1-harvest)=	0.839	
Current/Future Harvest (Recent A:B ratio * B cap of 17%))		0.101	(1-harvest)=	0.899	1.072
c. Combined Juvenile Passage and Harvest					
Yakima					
	Hist. D=0.8				**1.038**
	Hist. D=1.0				**0.913**
Umatilla					**1.138**
Warm Springs, Deschutes					**1.073**
Current to RPA					
a. Juvenile Passage Survival					
Yakima: SIMPAS "current" MCN-BON				0.588	
Yakima: SIMPAS "RPA" MCN-BON				0.677	1.152
Umatilla: SIMPAS "current" JDA-BON				0.651	
Umatilla: SIMPAS "RPA" JDA-BON				0.741	1.138
Warm Springs, Deschutes: SIMPAS "current" TDA-BON				0.758	
Warm Springs, Deschutes: SIMPAS "RPA" TDA-BON				0.846	1.117
b. Adult Passage Survival					
Current =	0.972 per project				
	Yakima - four projects			0.893	
	Umatilla - three projects			0.918	
	Warm Springs, Deschutes - two projects			0.945	
RPA =	0.98 per project				
	Yakima - four projects			0.922	1.033
	Umatilla - three projects			0.941	1.025
	Warm Springs, Deschutes - two projects			0.960	1.017

Table A-23 (continued). Estimates of proportional change in MCR steelhead survival associated with proposed action (current), RPA, and breaching four Snake River dams. Bold estimates define range considered in subsequent analyses.

	Survival Estimate	Proportional Change
c. Combined Juvenile and adult change from current to RPA		
Yakima		1.190
Umatilla		1.166
Warm Springs, Deschutes		1.135
Combined Base-to-Current and Current -to-RPA Change:		
Yakima		
Hist. D=0.8		**1.236**
Hist. D=1.0		**1.087**
Umatilla		**1.327**
Warm Springs, Deschutes		**1.218**

A.5.8.2 Survival Rate Change Associated With the RPA

Implementing the hydrosystem component of the RPA will proportionally increase both juvenile and adult survival through the four lower Columbia River projects beyond the current level associated with the proposed action.

Juvenile Passage Survival. NMFS evaluated the expected juvenile survival change based on a comparison of SIMPAS model results for operations associated with the proposed action and the RPA, given 1994-to-1999 water conditions. NMFS estimates that the hydrosystem component of the RPA will increase recent average Yakima River stock juvenile survival from McNary pool to Bonneville Dam (58.8%) by approximately 15.2%, to a new survival rate of 67.7% (Table 9.7-5; Table A-23). NMFS estimates that the hydrosystem component of the RPA will increase recent average Umatilla River stock juvenile survival from the John Day pool to Bonneville Dam (65.1%) by approximately 13.8% to a new survival rate of 74.1% (Table 9.7-5; Table A-23). The RPA is expected to increase the recent average Deschutes and Warm Springs stock juvenile survival from The Dalles pool to Bonneville Dam (75.8%) by approximately 11.7%, to a new survival rate of 84.6% (Table 9.7-5; Table A-23).

Adult Passage Survival. Recent average Middle Columbia River (MCR) steelhead adult survival through two to four projects is 89.3% for the Yakima stock, 91.8% for the Umatilla stock, and 94.5% for the Deschutes and Warm Springs stocks (Table 9.7-5). NMFS estimates that, after implementing the RPA, adult survival will increase from the recent average to 92.2% for the Yakima stock, 94.1% for the Umatilla stock, and 96% for the Warm Springs and Deschutes stocks (Table 9.7-5). These changes represent proportional survival increases ranging from 1.7% to 3.3% (Table A-23).

Summary. The product of the proportional survival improvements associated with the current conditions (Section A.5.8.1) and the RPA results in an expected survival improvement of 9% to 24% (1.09 to 1.24 times the base survival rate) for the Yakima stock, 33% (1.33 times the base survival rate) for the Umatilla stock, and 22% (1.22 times the base survival rate) for the Deschutes and Warm Springs stocks (Table A-23). The range of survival change estimates for the Yakima stock represents historical D estimates of 0.8 and 1.0 (Table A-21).

A.5.8.3 Survival Rate Change Associated With Breaching

No quantifiable survival improvements are expected for this ESU after four Snake River dams are breached.

A.5.9 Lower Columbia River Steelhead

The current population trends and needed survival changes summarized for this ESU in Tables A-2 through A-6 refer only to spawning aggregations below Bonneville Dam. Operation of the FCRPS under the actions considered in this analysis may influence survival or spawning success of these aggregations, but NMFS is unable to quantify those effects.

A.5.10 Upper Willamette River Steelhead

NMFS is unable to quantify any survival changes for this ESU as a result of any of the actions evaluated in the analysis.

A.5.11 Columbia River Chum Salmon

The current population trends and needed survival changes summarized for this ESU in Tables A-2 through A-6 refer only to spawning aggregations below Bonneville Dam. Operation of the FCRPS under the actions considered in this analysis may influence survival or spawning success of these aggregations, but NMFS is unable to quantify those effects.

A.6 ESTIMATES OF ADDITIONAL NEEDED SURVIVAL IMPROVEMENTS AFTER IMPLEMENTING THE PROPOSED ACTION, RPA, AND BREACHING

NMFS compared the expected survival improvements from each action described in Section A.5 with the survival improvements needed to meet survival and recovery indicator criteria, which were estimated in Section A.4. NMFS estimated the additional needed survival improvement after implementing an action by dividing the needed survival change from Section A.4 by the expected survival change from Section A.5. The results are summarized in tables in Sections 6.3, 9.7.2, and 9.7.3.2 of the biological opinion and are not reproduced in this Appendix. Spreadsheets used to generate the ratios in those tables are available from the NMFS Hydro Program upon request.

A.7 Sensitivity Analysis to 10-Year Delay

The simple analytical approach used in this biological opinion assumes that all survival changes are instantaneous (McClure et al. 2000c). To the extent that improvements are implemented gradually, the analysis underestimates the survival change that ultimately will be required to meet survival and recovery indicator criteria. The magnitude of the additional change depends upon the current trend of the stock under consideration and the length of the delay. To demonstrate the effect of this assumption on the ability to meet the 48-year recovery indicator criterion, NMFS evaluated a 10-year delay in implementing the hydrosystem component of the RPA and in achieving any survival improvements in other life stages. The analysis also assumed that there has been no change from average base period survival as a result of current hydrosystem operations or reduced harvest rates.

NMFS first began with the geometric mean abundance of wild spawners from the eight most recent years used by McClure et al. (2000c) to estimate lambda. The raw spawner counts and proportion wild spawners were from the "Digital Appendices" spreadsheet that accompanies McClure et al. (2000c). The geometric mean cannot be estimated if zero spawners returned in any year. For index stocks with zeros in the most recent eight years, one spawner was added to the spawner count in each year before estimating the geometric mean (Sokal and Rohlf 1969). Table A-24 displays the resulting geometric means for the SR spring/summer chinook index stocks, the SR fall chinook aggregate, and the UCR spring chinook populations.

NMFS then projected the expected 8-year geometric mean population levels in 10 years ($\boldsymbol{n}_{(t+10)}$), given the current population level ($\boldsymbol{n}_{(t)}$) and the range of base period population growth rates (λ) estimated by McClure et al. (2000c):

(13) $$\boldsymbol{n}_{(t+10)} = \boldsymbol{n}_{(t)} * \lambda^{10}$$

The lambda needed to meet the 48-year recovery indicator criterion, after the 10-year delay, was estimated by substituting $\boldsymbol{n}_{(t+10)}$ for $\boldsymbol{n}$ in Equation 3. When applying Equation 3, NMFS used a 44-year period for estimation of the 48-year recovery criterion and a 34-year period for the 10-year delay. These time periods reflect the centering of the 8-year geometric means with respect to the end of the 48-year recovery period. NMFS then estimated the corresponding survival rate change from base period survival according to Equation 1. Finally, NMFS divided the new estimate of the needed survival rate change by the survival rate change expected from the RPA, and compared the additional survival rate change that would be necessary after a 10-year delay with that which would be necessary with immediate achievement of current and RPA hydrosystem survival improvements. Results are displayed in Table A-24.

For SR spring/summer chinook, the Imnaha river index stock required the greatest survival rate change after a 10-year delay in achieving current and RPA survival rates. Given these assumptions, a 57% to 95% survival improvement would be necessary at the end of 10 years to meet the recovery indicator criteria. In contrast, the estimate from the analysis that assumes instantaneous survival changes is a 26% to 66% needed survival improvement (Table 9.7-6 of

Table A-24. Effects of 10-year delay in achieving estimated current survival rates and estimated survival improvements associated with hydrosystem actions in RPA. Effects are evaluated with respect to achieving 48-year recovery indicator criterion, according to methods described in Section A-7.

	1980-Most Recent Year Lambda		Current 8-yr Geomean Wild Spawners	Expected Spawners in 10 Years If No Change		Change In Survival From 1980-99 Lambda Needed to Meet Recovery Criterion After 10-Year Delay		Additional Needed Change In Survival After Implementing RPA in 10 Years		Additional Needed Change In Survival If RPA Is Implemented Immediately (From Section 9.7.2)	
Spawning Aggregation	**Low**	**High**		**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Snake River Spring/Summer Chinook Salmon											
Bear Valley/Elk creeks	1.02	1.03	110	130.5	146.0	1.15	1.19	***0.83***	***0.92***	0.79	0.89
Imnaha River	0.88	0.92	122	34.0	54.4	2.18	2.53	***1.57***	***1.95***	1.26	1.66
Johnson Creek	1.01	1.03	90	99.1	125.5	0.99	1.07	***0.72***	***0.82***	0.70	0.83
Marsh Creek	0.99	1.00	23	20.0	23.2	1.51	1.59	***1.09***	***1.22***	0.98	1.12
Minam River	0.93	1.02	47	23.6	55.2	1.34	1.73	***0.97***	***1.33***	0.84	1.28
Poverty Flats	0.99	1.02	253	233.8	322.0	1.06	1.17	***0.77***	***0.90***	0.73	0.90
Sulphur Creek	1.04	1.05	15	22.7	25.3	1.12	1.16	***0.81***	***0.89***	0.78	0.87
Aggregate SR Fall Chinook	0.87	0.92	318	80.7	136.2	2.16	2.51	***1.16***	***1.69***	0.93	1.44
Upper Columbia River Spring Chinook											
Methow River - CRI	0.85	0.89	80	15.2	26.3	2.95	3.48	***1.78***	***2.39***	1.32	1.90
Entiat River - CRI	0.81	0.89	48	6.0	15.0	2.82	3.69	***1.82***	***2.70***	1.32	2.19
Wenatchee River - CRI	0.80	0.85	279	28.5	55.1	3.76	4.61	***2.65***	***3.68***	1.84	2.78

the biological opinion). For other SR spring/summer chinook index stocks, the 10-year delay would have a smaller effect on the needed survival changes.

For SR fall chinook salmon, no additional survival changes are needed under the low estimate when instantaneous survival changes are assumed (Table 9.7-7). However, a 10-year delay in achieving current and RPA hydrosystem survival improvements would mean that additional survival improvements would be necessary under both high and low estimates of the necessary change. The low estimate would change from 0% additional change with no delay to a 16% additional change with a 10-year delay. The corresponding high estimates are 44% and 69% for immediate implementation and the 10-year delay, respectively.

The 10-year delay in achieving current and RPA hydrosystem survival improvements would result in greater necessary survival improvements for UCR spring chinook than for SR spring/summer chinook or SR fall chinook. The Wenatchee population's low estimate of additional needed survival changes, given immediate implementation (84%; Table 9.7-8 of the biological opinion), would increase to 165% if there were a 10-year delay. The corresponding high estimates are 178% and 268% for immediate implementation and the 10-year delay, respectively.

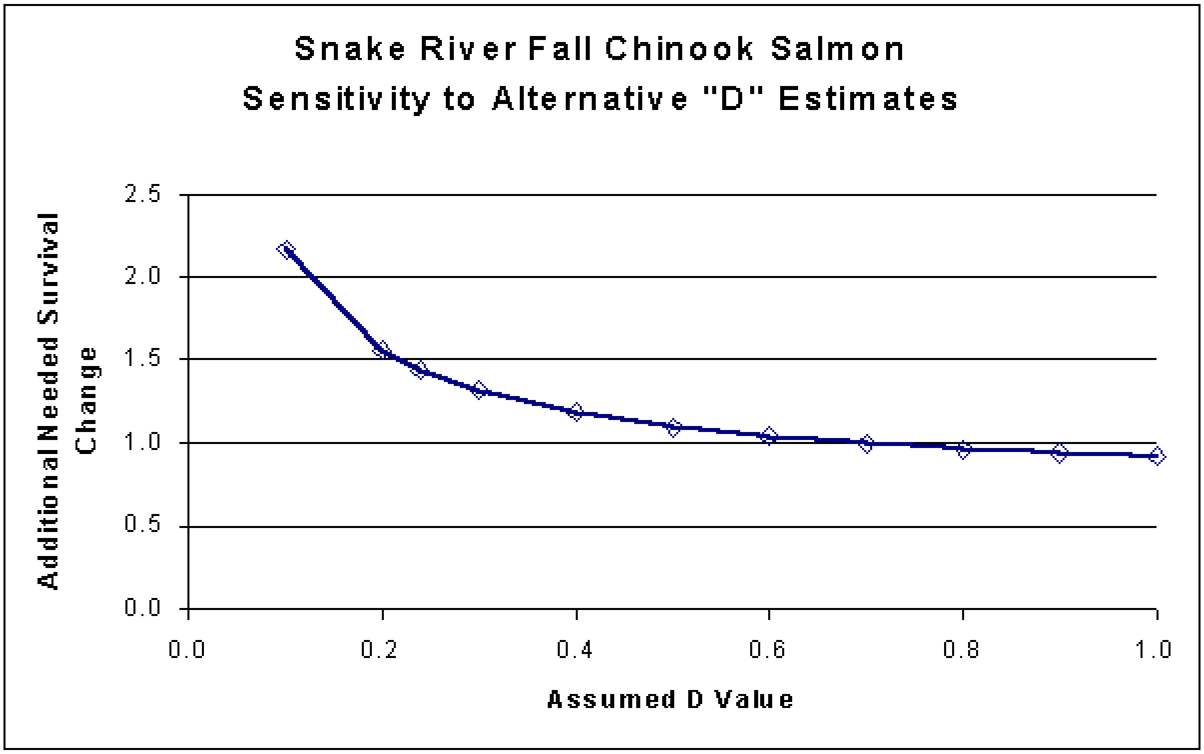
NMFS considered these sensitivity analyses qualitatively when drawing conclusions in the biological opinion.

A.8 SENSITIVITY ANALYSIS TO ALTERNATIVE SR FALL CHINOOK D ESTIMATES

NMFS did not estimate differential post-Bonneville survival (D) of SR fall chinook salmon. PATH generated several alternative estimates ranging from 0.05 to 1.00 and NMFS applied PATH's estimate of 0.24 in these analyses (Section A.5.2). NMFS investigated the sensitivity of fall chinook results to alternative estimates of D for one of the two alternative methods of estimating base-to-current juvenile passage survival changes (Method 1 of Section A.5.2.1, Tables A-10 and A-11), NMFS applied a range of D estimates (0.1 through 1.0, in 0.1 increments). This involved changing the D estimate in the PATH retrospective analysis, the PATH A2 analysis, the SIMPAS current analysis, and the SIMPAS RPA analysis.

Results are summarized in Figure A-2. Using this method, more fish are estimated to be transported under the proposed action and RPA than were transported during the base period. As D increases, RPA survival improves at a faster rate than base period survival improves. The result is that, if D is higher than 0.24, a smaller survival improvement is needed after implementation of the hydrosystem action in the RPA. No additional survival improvement is needed if D is about 0.7 or higher. However, if D is lower than 0.24, considerably higher survival improvements are needed than those estimated in the biological opinion (Table 9.7-7).

Figure A-2. Sensitivity of SR fall chinook salmon results to alternative assumptions regarding differential post-Bonneville survival of transported fish compared with nontransported fish (D). The D estimate used in the biological opinion was 0.24.



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Annex 1

Estimation of Hydrosystem Survival Under Natural Conditions

This annex discusses the methods used by NMFS to estimate survival rates that might occur in the free-flowing reach of the Snake River following dam breaching. The information is used in the body of Appendix A and in the biological opinion to compare the RPA and dam breaching with respect to achieving survival and recovery indicator criteria. Estimates are also generated for the entire reach encompassed by the mainstem FCRPS to compare an approximation of the mortality that might occur under natural conditions with the incidental take estimated for FCRPS operations. This comparison is noted in the incidental take statement.

A1.1 Estimates of Juvenile Passage Survival

NMFS used a two-step method to estimate juvenile survival under free-flowing conditions. First, it determined the average survival rate (expressed as a function of distance) of the species of interest through a river reach that is similar to that expected in the lower Snake and lower Columbia rivers in the absence of the FCRPS. NMFS then expanded these rate estimates to represent the distance each ESU must traverse through the reach proposed for breaching and through the entire FCRPS.

The best available estimates for survival of yearling chinook salmon and steelhead through free-flowing river reaches came from wild PIT-tagged smolts captured and released at the Whitebird trap on the Salmon River and subsequently detected at Lower Granite Dam between 1993 and 1998 (Smith et al. 1998; Hockersmith et al. 1999; Smith et al. 2000a,b; Tables A1-1 and A1-2; and "Natural" worksheets in Draft Biological Opinion spreadsheets). These cumulative survival estimates included passage through the impounded Lower Granite Reservoir and Lower Granite Dam. NMFS estimated survival through Lower Granite Dam and the reservoir from direct estimates made from 1993 through 1995 (chinook), 1994 through 1996 (steelhead), and extrapolations for other years from Williams et al. (in review). NMFS divided the cumulative survival from Whitebird trap to Lower Granite Dam by the estimate of Lower Granite Reservoir and dam survival for each year to obtain an estimate of cumulative survival through the free-flowing reach (Tables A1-1 and A1-2).

The distance between the Whitebird trap and the head of Lower Granite pool is 181 km. Therefore, survival per-km through the free-flowing reach was the 181st root of the cumulative survival rate. For wild yearling chinook, this resulted in a mean estimated free-flowing reach survival rate of 0.99961/km. The corresponding mean survival rate for steelhead was 0.99966/km.

Similar estimates were also available for survival from traps upstream of Whitebird on the Salmon River and from the Imnaha River trap. Estimates of survival per km from these traps

Table A1-1. Summary of NMFS yearling chinook salmon free-flowing reach survival estimates.

	Surv Trap-Lower Granite Dam (LGR)		Surv[a]	Surv Trap-Head Res[b]		Surv per km[b]	
	Imnaha	**Salmon**	**LGR Res**	**Imnaha**	**Salmon**	**Imnaha**	**Salmon**
1993	0.81	0.83	0.90	0.90	0.93	0.99887	0.99960
1994	0.76	0.79	0.92	0.83	0.86	0.99791	0.99919
1995	0.91	0.86	0.92	0.99	0.94	0.99984	0.99963
1996	0.81	0.82	0.90	0.91	0.92	0.99889	0.99951
1997	0.90	NA[c]	0.90	1.00	NA[c]	0.99995	NA[c]
1998	0.85	0.93	0.94	0.91	0.99	0.99897	0.99993
1999	0.88	0.91	0.94	0.94	0.97	0.99926	0.99982
Trap Mean	0.85	0.86		0.92	0.93	0.99910	**0.99961**
Std. Dev.	0.05	0.05		0.06	0.04	0.00069	0.00026

a. Williams et al. (In review).

b. Head of reservoir assumed at Snake River trap; see below for distances.

c. No wild chinook salmon tagged.

Notes: Material used in this table was taken from S. Smith (NMFS) June 12, 2000, trap.xls spreadsheet. "Salmon" refers to releases from Whitebird trap on the Salmon River; "Imnaha" refers to releases from the Imnaha River trap. Bold survival rate was used in all July 27, 2000, Draft Biological Opinion analyses.

	PTAGIS Rkm	km to LGR
Salmon Trap	522.303.103	181
Imnaha Trap	522.308.007	90
Snake Trap	522.23	
Lower Granite	522.17	

Table A1-2. Summary of NMFS yearling steelhead free-flowing reach survival estimates.

	Surv Trap-LGR		Surv[a]	Surv Trap-Head Res[b]		Surv per km[b]	
	Imnaha	Salmon	LGR Res	Imnaha	Salmon	Imnaha	Salmon
1993	0.76	0.83	0.91	0.83	0.91	0.99797	0.99948
1994	0.66	0.77	0.90	0.73	0.85	0.99645	0.99913
1995	0.84	0.89	0.91	0.92	0.98	0.99905	0.99988
1996	0.87	0.96	0.94	0.92	1.01	0.99905	1.00008
1997	0.90	NA[c]	0.92	0.97	NA[c]	0.99971	NA[c]
1998	0.86	0.89	0.90	0.96	0.99	0.99952	0.99997
1999	0.88	0.82	0.91	0.97	0.90	0.99963	0.99939
Trap Mean	0.82	0.86		0.90	0.94	0.99877	**0.99966**
Std. Dev.	0.09	0.07		0.09	0.06	0.00118	0.00037

a. Williams et al. (In review).

b. Head of reservoir assumed at Snake River trap; see below for distances.

c. No wild chinook salmon tagged.

Note: Material used in this table was taken from S. Smith (NMFS) June 12, 2000, trap.xls spreadsheet. "Salmon" refers to releases from Whitebird trap on the Salmon River; "Imnaha" refers to releases from the Imnaha River trap. Bold survival rate was used in all July 27, 2000, Draft Biological Opinion analyses.

	PTAGIS Rkm	km to LGR
Salmon Trap	522.303.103	181
Imnaha Trap	522.308.007	90
Snake Trap	522.225	
Lower Granite	522.171	

were consistently lower than estimates for fish released from the Whitebird trap (Tables A1-1 and A1-2; Paulsen 2000). NMFS did not incorporate the Imnaha trap or other Salmon River traps into the estimates of natural survival. Traps in the Salmon River above Whitebird and the Imnaha trap releases were not used in natural survival estimates for the following reasons:

- The other Salmon River trap estimates were already captured in the Whitebird to Lower Granite estimate, because it included fish from all of the tributaries caught at the upstream traps.

- The Whitebird estimate is through a river reach that is more similar to the reach below Lower Granite Dam (in terms of river width, depth, and flow characteristics) than are the reaches farther up in the tributaries. The Imnaha trap is in a tributary habitat that is also less similar to the reach below Lower Granite Dam than is the Whitebird trap.

- The upstream traps are closer to spawning areas, so survival rates from those traps probably represent a culling process that would be greater than that included in the survival rate below Whitebird. Culling can result from size, degree of smoltification, or river stretches through which the smolts migrated. The river reach from Whitebird to Lower Granite is more similar to the free-flowing lower Snake and lower Columbia than is the reach from Salmon River tributaries to Lower Granite. Imnaha trap estimates were not used because the trap is closer to the spawning grounds than is the Whitebird trap.

To test the hypothesis that survival is lower in reaches closer to spawning grounds than in reaches farther downstream, survival of Whitebird and Imnaha releases was compared in the reach between each trap and Lower Granite Dam and in two reaches below Lower Granite Dam (Tables A1-3 and A1-4). Survival between the Imnaha trap and Lower Granite Dam, expressed as a per-km rate, was much lower than that between the Whitebird trap and Lower Granite Dam (Tables A1-1 and A1-2), whereas survival estimates for the two traps were nearly identical when compared between Lower Granite Dam and Little Goose Dam and between Little Goose Dam and Lower Monumental Dam. This suggests that, after initial losses of fish occur, there are no inherent differences in smolt survival between stocks released at Imnaha and Whitebird. Thus, the Whitebird trap provides the best estimates of expected survival in downstream stretches of natural river.

Table A1-5 shows how the yearling chinook and yearling steelhead survival rates were expanded to approximate the natural survival rates of each chinook and steelhead ESU. NMFS first determined the maximum distance that any population within an ESU travels through the hydrosystem or through the reach affected by Snake River dam breaching. The cumulative natural survival rate for an ESU was then the mean survival rate per km, raised to the power of the number of km traveled through the hydrosystem. For example, UCR spring chinook pass through 287 km of the FCRPS and are assumed to have the same natural survival rate as SR spring/summer chinook. Their expected natural survival through the FCRPS reach is 89.5% ($0.999614283^{286.9}$).

Table A1-3. Survival estimates for Whitebird trap (Salmon R.) spring/summer chinook releases and Imnaha trap spring/summer chinook releases.

	Surv LGR-LGO		Surv LGO-LMN		Surv LGR-LMN	
	Imnaha	Salmon	Imnaha	Salmon	Imnaha	Salmon
1993	0.78	0.87	NA	NA	NA	NA
1994	0.86	0.75	0.82	0.89	0.71	0.67
1995	0.92	0.91	0.97	1.00	0.90	0.91
1996	0.91	0.91	0.86	1.00	0.78	0.90
1997	0.99	NA	0.95	NA	NA	NA
1998	1.02	1.02	0.85	0.81	0.87	0.83
1999	0.98	0.95	0.91	0.93	0.89	0.88
Trap Mean	0.92	0.90	0.89	0.92	0.828	0.837
Std. Dev.	0.09	0.09	0.06	0.08	0.08	0.10

Note: These releases move through river reaches below Lower Granite Dam. Estimates from NMFS PIT-tag studies are described in text. From spreadsheet “trap.xls” prepared by S. Smith (NMFS).

Table A1-4. Survival estimates for Whitebird trap (Salmon R.) steelhead releases and Imnaha trap steelhead releases.

	Surv LGR-LGO		Surv LGO-LMN		Surv LGR-LMN	
	Imnaha	Salmon	Imnaha	Salmon	Imnaha	Salmon
1993	1.02	0.76	NA	NA	NA	NA
1994	0.82	0.81	0.74	0.73	0.60	0.59
1995	0.88	0.96	1.09	0.94	0.96	0.90
1996	0.87	0.87	1.00	1.25	0.87	1.09
1997	1.02	NA	0.83	NA	NA	NA
1998	1.00	0.87	0.82	0.77	0.82	0.67
1999	0.99	1.14	0.88	0.82	0.86	0.93
Trap Mean	0.94	0.90	0.89	0.90	0.823	0.835
Std. Dev.	0.08	0.13	0.13	0.21	0.13	0.20

Note: These releases move through river reaches below Lower Granite Dam. Estimates from NMFS PIT-tag studies are described in text. From spreadsheet “trap.xls” prepared by S. Smith (NMFS).

Table A1-5. Summary of mean per-km juvenile survival rates through free-flowing river reaches and expansions to the reach associated with Snake River dam breaching and with the entire FCRPS.

ESU	Mean Per-Km Survival	Entire FCRPS # Km	Mean Survival	Snake River Breach	Breach Mean Survival
Snake Sp/Sum CH	0.999614283	512	0.821	210	0.922
Snake SH	0.999656110	512	0.838	210	0.930
Snake Fall CH (Method A)	0.997800000	512	0.324	210	0.630
Snake Fall CH (Method B)	0.999500000	512	0.774	210	0.900
UCR Spring CH	0.999614283	287	0.895		
UCR SH	0.999656110	287	0.906		
MCR SH	0.999656110	287	0.906		
LCR CH Yearlings	0.999614283	34.5	0.987		
LCR CH Subs (Method A)	0.997800000	34.5	0.927		
LCR CH Subs (Method B)	0.995000000	34.5	0.841		
LCR SH	0.999656110	24.1	0.992		

Empirical estimates of free-flowing reach survival for juvenile SR fall chinook salmon is more limited and difficult to interpret. The PATH participants used two methods to group and extrapolate recent PIT-tag survival estimates (Peters et al. 1999). The first (designated method A) results in a free-flowing survival rate of 0.9978 per km, and the second (designated method B) in a rate of 0.9995 per km.

Method A was based on the premise that survival from release to Lower Granite for fish released at Pittsburgh Landing encompasses survival through the free-flowing Snake River (the 122 km from release to the head of Lower Granite Reservoir) and a project survival through Lower Granite Reservoir and the dam. After the project survival is divided out of the total survival, the free-flowing survival remains. To estimate Lower Granite project survival, PATH used the mean survival through the two projects below Lower Granite: Little Goose and Lower Monumental.

To obtain the average for all release groups, PATH weighted each survival estimate by the proportion of the total run of wild fish that were sampled in the period that included the release date as its midpoint. In addition, each survival estimate was weighted by the inverse of the relative variance. The relative variance is defined as the variance divided by the estimated survival. This removes some of the bias of lower survivals having lower variance (S. Smith, NMFS, pers. comm. to PATH 1998). For this weighting, the variances were from survival through the entire segment (release to Lower Monumental), since all this information was used in the estimates. Both of these weights were normalized to add to 1.0 so that neither weight would have more influence than the other. Separate estimates of survival through the free-flowing reach were made for each release (19 total) from 1995 to 1998. Each estimate was then weighted, and the geometric mean of all the estimates was computed. The resulting survival rate estimate was 0.9978 per km.

Peters et al. (1999) state that the method B juvenile survival rate was estimated from NMFS' reported survival rate estimates for PIT tagged fall chinook in 1998, 1997, and 1995 (Muir and Smith 1998, Muir et al. 1998). The value was computed by comparing survival rates from different points of release in the Snake River above the confluence of the Snake and Clearwater Rivers. The ratio of the survival rate estimate for the upstream release site (Pittsburgh Landing – PL) to that of the downstream release site (Billy Creek – BC) was used to derive free-flowing Snake River survival estimates. The ratio was calculated for each release group, then the release group estimates were averaged. The length of the PL-to-BC reach (81 km) was then used to obtain a per-km survival rate, which equaled 0.9995.

NMFS found that both methods were credible and that there was no basis for concluding that one better represented the best available scientific information, NMFS used both methods, therefore, to establish a range of likely natural survival estimates. When expanded to the 512-km reach, method A estimates an average survival of 32.4% versus 77.4% for method B (Table A1-5).

A1.2 Estimates of Adult Passage Survival

NMFS considered three methods for estimating expected survival of adults in the absence of the FCRPS. NMFS concluded that the third method described below was most reasonable, and that method was the only one applied in the Draft Biological Opinion.

A1.2.1 PATH Method

The PATH participants estimated free-flowing survival of wild SR spring/summer chinook salmon as 97% cumulative survival through the Snake River if four dams are breached (equivalent to 99% per project). Although the derivation of this estimate is not explicitly described in Marmorek et al. (1998) or Marmorek and Peters (1998a,b), personal communications indicate that it was obtained by applying the absolute difference in Bjornn's (1989) mean dam-count to redd-count ratios at Ice Harbor Dam for two periods, 1962 through 1968 and 1975 through 1988, to estimates of current adult passage survival through that reach. Ice Harbor was the farthest upstream FCRPS project during the first period. PATH interpreted the 9% difference (3% per project) between the mean ratios for each period as the mortality caused by the three dams that were constructed above Ice Harbor during the latter period (1975 through 1988). Extrapolating Bjornn's (1989) result from three dams to the four dams proposed to be breached, PATH estimated that adult survival would improve 12% if the four lower Snake River dams were breached. PATH estimated the current passage survival at 85%, based on conversion rates in Beamesderfer et al. (1998) and concluded that the survival rate through the four lower Snake River projects would be 97% (85% + 12%) after breaching.

The essential implication of this method is that PATH estimated a 99.24% per-project natural survival rate for adult spring/summer chinook salmon ($0.97^{(1/4)}$). PATH concluded that this same survival rate applies to SR fall chinook (Peters et al. 1999) without explanation. If NMFS applied this approach to estimates of natural survival through the entire FCRPS, it would conclude that adults of all SR ESUs have a natural survival rate of 94% through eight FCRPS projects, UCR and MCR ESUs have a natural survival rate through up to four FCRPS projects of 97%, and populations of LCR ESUs that spawn above Bonneville Dam have a natural survival rate of 99% through one project.

NMFS has several concerns regarding this approach. The method assumes that survival from the current location of the head of Lower Granite pool to the various spawning areas did not change between the two periods described in Bjornn (1989), and that redd counts represented a constant fraction of total spawners in the Salmon, Grande Ronde, and Imnaha River systems during each period. Neither assumption was discussed or substantiated by PATH, and the assumption's validity is questionable given the variation in more recent estimates, as described below. To apply the 9% change in survival to current survival, one must assume that there has been no change from adult survival during Bjornn's (1989) second period to the present. As described in Appendix C, NMFS believes that adult survival through the FCRPS has been relatively constant since 1980, but it has not drawn the same conclusion for the period beginning in 1975. NMFS also concludes that adult survival is better described by radiotelemetry than by conversion rates. If the 3% per project survival improvement following dam removal was applied to the current SR spring/summer chinook adult survival estimate (0.972; Table 6.1-1 of Draft Biological Opinion), the natural survival rate would be slightly higher than 100%. Finally, a significant drawback of this method is the lack of comparable information for species other than SR spring/summer chinook. PATH assumed that the absolute estimate for spring/summer chinook should be applied to fall chinook (Peters et al. 1999). Given the lower current survival rate of fall chinook (Table 6.1-1 of Draft Biological Opinion), however, equally reasonable alternatives would have been to apply a 3% survival improvement per project to the current fall chinook survival rate or to conclude that the effect of dams on fall chinook cannot be inferred from the effects of dams on spring chinook.

A1.2.2 Direct Estimates of Free-flowing Reach Survival

A second method evaluates the survival of radio-tagged adults through free-flowing reaches above Lower Granite Dam, in a manner similar to that used to estimate juvenile survival. Bjornn et al. (1995) estimated adult loss of spring chinook salmon from Ice Harbor Dam to reference points in tributaries to the Snake River above Lower Granite Dam (Table A1-6). Bjornn et al. (1995) estimated survival from Ice Harbor to Lower Granite (footnotes to Table A1-6), and NMFS adjusted total survival rates to derive estimates of survival through the free-flowing reach above Lower Granite Dam. The resulting survival rate averaged 0.9994 per km, equal to 73.5% survival through the 512-km reach encompassing the entire hydrosystem. This is equivalent to a natural survival rate of 96% per project, for eight projects.

NMFS also has concerns about this second approach, which may underestimate survival of adults through free-flowing river sections. One potential problem is the degree to which radio-tagged adults migrating through free-flowing reaches above Lower Granite Dam represent adults that would be migrating through a free-flowing reach between Bonneville and Lower Granite. The experience of migrating 512 km past eight dams probably influences the survival upstream of Lower Granite Dam. The method assumes that there is no effect caused by migrating 512 km and no delayed effects due to passing eight dams. The method also assumes that the free-flowing river reaches above Lower Granite are comparable to the reaches between Bonneville and Lower Granite. The end points of the reaches were chosen to avoid inclusion of passage through spawning tributaries that clearly would not represent mainstem passage, but the degree to which the chosen reaches represent conditions below Lower Granite is debatable. One additional concern is that, as with the first method, this approach is not applicable to all species because radiotelemetry estimates are not available.

Table A1-6. Estimates of SR spring/summer chinook survival in free-flowing river sections to spawning stream entrance calculated by radiotelemetry (Bjornn et al. 1995).

Year	Wild/ Hatchery	Survival from Uppermost Dam	Reach	Uppermost Dam Project Survival	Mainly River Survival (1)	KM Mainly River	River Survival/ KM	4-Pool River Survival/ 20 KM	BON-LGR River Survival/ 512 KM	Reference
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Upper Salmon River (North Fork)	0.967	0.6187	**685.4**	0.9993	0.8632	0.6987	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Upper Salmon River (North Fork)	0.958	0.7482	**685.4**	0.9996	0.9194	0.8148	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Upper Salmon River (North Fork)	0.98	0.8370	**685.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Middle Fork Salmon River	0.967	0.6187	**624.4**	0.9992	0.8453	0.6638	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Middle Fork Salmon River	0.958	0.7482	**624.4**	0.9995	0.9003	0.7741	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Middle Fork Salmon River	0.98	0.8370	**624.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in South Fork Salmon River	0.967	0.6187	**561.4**	0.9991	0.8277	0.6306	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in South Fork Salmon River	0.958	0.7482	**561.4**	0.9995	0.9003	0.7741	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in South Fork Salmon River	0.98	0.8370	**561.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Imnaha River	0.967	0.6187	**322.4**	0.9985	0.7297	0.4637	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Imnaha River	0.958	0.7482	**322.4**	0.9991	0.8277	0.6306	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Imnaha River	0.968	0.8370	**322.4**	0.9994	0.8816	0.7354	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Grande Ronde River	0.967	0.6187	**277.4**	0.9983	0.6996	0.4185	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Grande Ronde River	0.958	0.7482	**277.4**	0.9990	0.8105	0.5991	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Grande Ronde River	0.98	0.8370	**277.4**	0.9994	0.8816	0.7354	Bjornn et al. (1995), fish RT at JDA
					Combined Weighted Mean Run-at-Large Estimate		0.9994	0.8816	0.7354	

(1) SURVIVAL FROM UPPERMOST DAM / UPPERMOST DAM PROJECT SURVIVAL = MAINLY RIVER SURVIVAL

Note: This material comes from a spreadsheet and table prepared by C. Pinney (Corps of Engineers) for Federal agency performance standards report.

Bjornn et al. (1995) note: Survival IHR ladder exit to LGR ladder exit = 90% in 1993 and 85% in 1992 (similar to untagged); success of passage IHR tailrace to LGR forebay = 81.3% in 1992 and 87% in 1993; success passage IHR tailrace to upper end LGR pool = 78.7% in 1992 and 75% in 1991; relative distribution of spr/sum chinook into tributaries of SR basin in 1993 = 5% Tuccannon River, 21% Clearwater River, 4% Snake River upstream of Lewiston, 11% Grande Ronde, 8% Imnaha, 51% Salmon rivers (natal tributaries).

A1.2.3 Qualitative Appraisal of Adult Natural Survival Rate

NMFS considers the best estimate of adult SR spring/summer chinook survival following breaching to be intermediate to estimates derived from the two methods described above. The survival rate expected to result from the RPA represents survival through an impounded reach with all possible improvements short of breaching. The estimate of adult survival, when the RPA is fully implemented, is 98% per project. This estimate is intermediate to the survival rate estimated by the first and second methods (96% and 99% per project, respectively).

In addition to the similarity of estimates of survival through impounded and unimpounded reaches, as described above, one of the reasons for concluding that adult survival under the RPA is equal to natural survival is the migration rates through the impounded FCRPS, which are very similar to those through unimpounded reaches. Studies supporting this observation are reviewed in the Basinwide Recovery Strategy (Federal Cascus 2000). Another reason is the description in NMFS (2000) of factors currently causing mortality of adults through the FCRPS and the Draft Biological Opinion's provision to ameliorate these sources of mortality through the RPA. One of the primary factors causing apparent, and to some extent actual, mortality of adults is fallback NMFS (2000) describes studies indicating that this problem is particularly severe for the Bradford Island fish ladder at Bonneville Dam, where fallback rates may be as high as 15%. Structural and operational measures in the RPA are expected to reduce inadvertent fallback and related mortalities (Draft Biological Opinion, Section 9.7.1.2). Another factor described in NMFS (2000) is occasional adult gas bubble disease during conditions of high gas supersaturation. The RPA also calls for a gas abatement program to reduce gas supersaturation. In general, the RPA is expected to reduce the current adult mortality rate, which is already estimated to be relatively low.

One advantage of this method for estimating the survival of SR spring/summer chinook salmon is that it is directly applicable to other ESUs, whereas the other two methods are not. Therefore, estimates of adult survival for all ESUs are as described in Draft Biological Opinion, Table 9.7-2. The expected survival rates are 71% for SR fall chinook salmon, 77.3% for SR steelhead, and 85.7% for SR sockeye salmon.

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